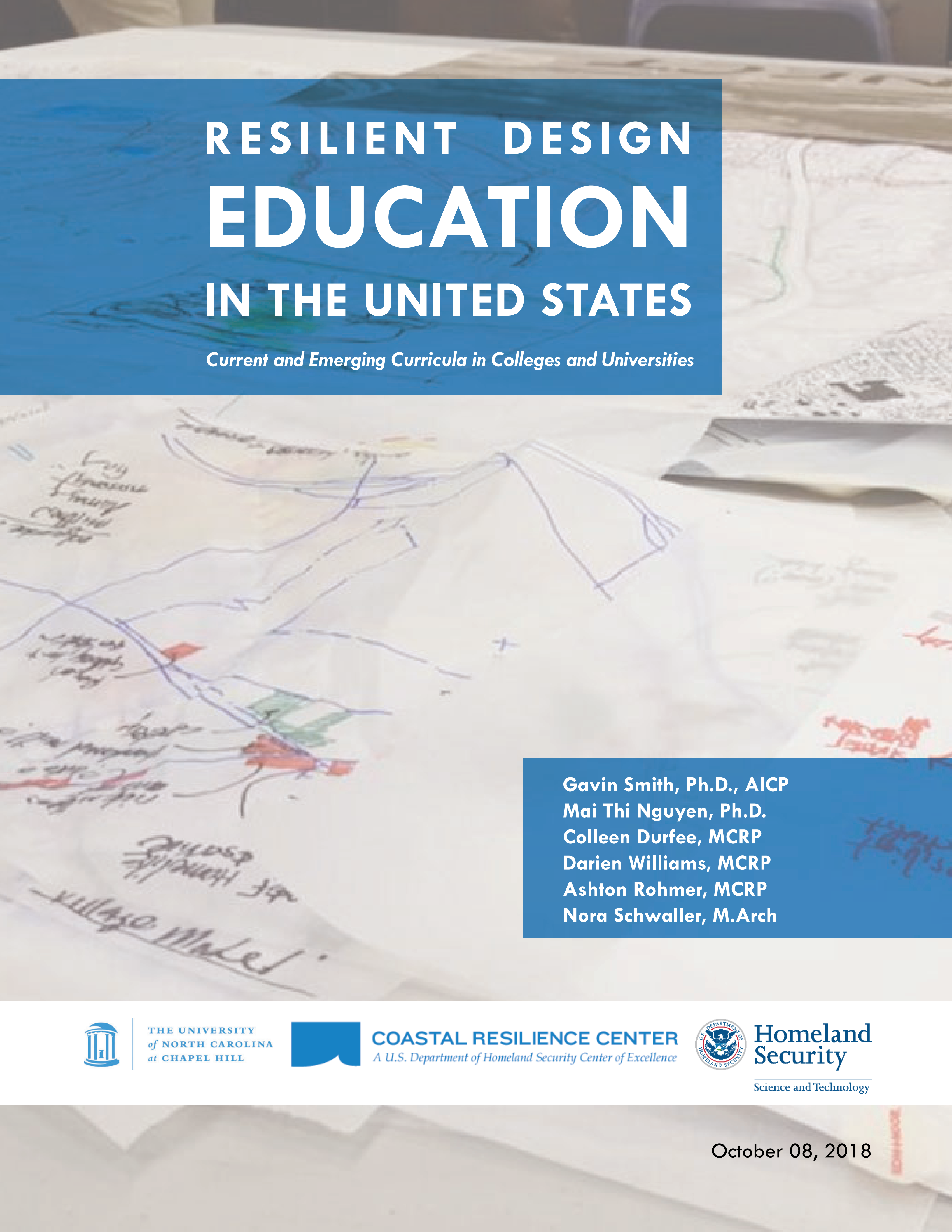


RESILIENT DESIGN EDUCATION IN THE UNITED STATES

Current and Emerging Curricula in Colleges and Universities

Gavin Smith, Ph.D., AICP
Mai Thi Nguyen, Ph.D.
Colleen Durfee, MCRP
Darien Williams, MCRP
Ashton Rohmer, MCRP
Nora Schwaller, M.Arch

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

COASTAL RESILIENCE CENTER
A U.S. Department of Homeland Security Center of Excellence

Homeland Security
Science and Technology

October 08, 2018

ACKNOWLEDGMENTS

This report is funded by the U.S. Department of Homeland Security Science and Technology Directorate's Office of University Programs, the Coastal Resilience Center of Excellence, and the University of North Carolina at Chapel Hill's Department of City & Regional Planning. We would like to thank our review committee and the experts we interviewed for this study, all of whom provided invaluable insights. We also appreciate research assistance from graduate students Amanda Martin and Abigail Moore in the early stages of this research and Nora Schwaller for her design expertise.

THANK YOU!

DEDICATION

This report is dedicated to David R. Godschalk, whose life's work in planning, natural hazards, and design has inspired multiple generations of scholars and practitioners. His role as an extraordinary educator, mentor, and friend has instilled in us an unwavering desire to create more resilient communities.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Two thousand and seventeen marks the costliest year on record for disasters in the United States. The damage toll for the sixteen disaster events that year totaled more than $309 billion (NOAA 2018). The rising cost of disasters and the human suffering that occur in the aftermath have made the call to design communities resiliently more important than at any other time in history.

Resilient design not only involves mitigating damage and allowing communities to absorb, adapt, and return to a steady state of equilibrium more rapidly post-disaster, but also reduces the likelihood of disasters occurring in the first place if there are proactive applications of sound resilient design approaches. Furthermore, should a disaster occur, resilient design facilitates a return to a new normal in which communities are defined by a more equitable and socially cohesive condition, local economies are diversified and robust, physical and social vulnerabilities are reduced, and the natural environment is protected and restored.

Although resilient design is an important and emerging field of inquiry, we have scant knowledge about how colleges and universities in the United States teach and train students who go on to become scholars and practitioners in this field. The methods used in this research involved an extensive internet search of resilient design curricula, key informant interviews with experts, consultation with a review committee, and case studies of resilient design education programs.

Our study finds that resilient design, as a field, is a small but rapidly growing area of study. There is an increasing number of individual courses taught as well as the creation of university degree, minor, and certificate programs focused on resilient design. The emerging focus on natural hazards, disasters, and resilient design in college and university curricula, while promising, remains highly varied. Resilient design courses and programs are frequently siloed in particular disciplines rather than serving as a venue to apply interdisciplinary systems thinking. Similarly, the majority of courses are developed in isolation rather than as part of degree, minor, or certificate programs.

Beyond curricula within academic units, research centers, institutes, and extension programs offer students project-based and experiential learning opportunities. These are spaces in which inter- and multi-disciplinary collaborations between faculty, students, and practitioners can take place through funded research or applied resilient design projects.

We studied five design-based disciplines, including architecture, building sciences, engineering, landscape architecture, and planning. The experts we interviewed, as well as those serving on our review committee, agreed that to design resiliently requires interdisciplinary, systems-based, and multi-scalar thinking because of the interdependencies embedded within and between the ecological, physical, and social environments.

GOALS AND ASPIRATIONS

To enhance and improve upon the delivery of resilient design curricula in U.S. colleges and universities, we identify the following goals and aspirations:

IMPROVE INSTITUTIONAL COMMITMENT

Colleges and universities must support individual commitments to resilient design education by scholars with a larger institutional commitment to resilient design education that spans multiple disciplines and associated departments.

DEVELOP NEW CURRICULA MODELS AND ORGANIZATIONAL STRUCTURES

There are few universities that incorporate interdisciplinary, systems-based, and multi-scalar elements of resilient design education to provide educational, research, and engagement opportunities. Universities must develop new curricula models and organizational structures that support this type of educational offering.

BUILD INTERDISCIPLINARY TEAMS

Resilient design is an inherently applied and interdisciplinary field. Therefore, colleges and universities should build interdisciplinary teams that include a mix of faculty, practitioners, and policymakers to teach and mentor students.

EMPHASIZE FIELD AND STUDIO-BASED PROJECTS

Resilient design curricula benefit from a learning by doing approach that provides a platform to be innovative, room to fail, and opportunity to redress problems. Field and studio-based projects should be a key element of any resilient design curricula because they provide this platform, enabling students and faculty to explore the multi-faceted nature of the challenges present in practice.

CREATE FLEXIBLE AND RESPONSIVE CURRICULA

Post-disaster conditions provide rich learning opportunities. Therefore, colleges and universities should create resilient design curricula that are responsive to opportunities that arise, including capitalizing on post-disaster situations.

MEET [AND EXCEED] THE NEEDS OF STAKEHOLDERS

In order to stay relevant, resilient design curricula should meet and attempt to exceed the needs of national, state, and local stakeholders. To facilitate this, colleges and universities should seek out partners external to the college/university that could serve as ongoing "clients" or sounding boards regarding curriculum content and the quality of products produced by students and faculty.

IMPACT

In the last year, the U.S. has experienced extreme weather events, including Hurricanes Harvey, Irma, and Maria, as well as wildfires in California, and flooding in Oklahoma, Missouri, and Arkansas, that have devastated homes and communities. Some places had never experienced such high levels of flooding, wind, and destruction. Others have experienced these repeat events due to the combined effects of extreme weather and the lack of resilient design. Our patterns of growth and development in the U.S. have placed homes and communities in the floodplain, along sensitive shorelines, and in other vulnerable and precarious places. The escalating costs of damage from disasters and the increasing intensity and frequency of weather-related events forces us to think about how we educate and train future design scholars and practitioners. The organizational and incentive structures in U.S. colleges and universities pose many barriers to delivering a high-quality resilient design education. This report identifies ways to eliminate these barriers and facilitate the delivery of an interdisciplinary, systems-based, multi-scalar education in resilient design.

INTRODUCTION


Photo Credit: Pok Rie

RISE OF RESILIENCE

Two thousand and seventeen marks the costliest year on record for disasters in the United States. The damage toll for the sixteen disaster events that year was highest on record at over $309 billion (NOAA 2018). The rising cost of disasters and the human suffering that occur in the aftermath have made the call to design communities resiliently more important than at any other time in history. Resilient design can mitigate damage and allow communities to absorb, adapt, and return to a steady state of equilibrium more rapidly post-disaster. Sound resilient design also enables communities to envision and implement measures that address pre-existing conditions that predispose them to disaster.

Although resilient design is an important and emerging field of inquiry, we have scant knowledge about how U.S. colleges and universities teach and train students who go on to become scholars and practitioners in this field. Furthermore, there is a range of design-related disciplines that offer resilient design curricula, yet there has not been a systematic inventory of delivery methods, such as courses, certificates, and degree programs being offered across these disciplines. At a more basic level, there is not a common definition of resilient design across fields and therefore, no consistent pedagogy around resilient design.

Resilience has become an increasingly important organizing principle for the design community, especially when thinking about how and where to build in relation to natural hazards and disasters. In addition, there is an expanding body of policy, research, and educational initiatives surrounding resilient design. Pre- and post-disaster policy initiatives that focus on resilient design include the Disaster Mitigation Act of 2000, the Post-Katrina Emergency Management Reform Act, Sandy Recovery Improvement Act of 2013, Presidential Policy Directive 8, and related shifts in grants and other forms of assistance, including efforts to improve the role of governance. Additional measures include federal agency partnerships with foundations, such as the U.S. Department of Housing and Urban Development's one billion-dollar funding of the Rockefeller Foundation-led Rebuild by Design competition initiated following Hurricane Sandy, the Federal Emergency Management Agency's (FEMA) Community Resilience Innovation Challenge, and the Rockefeller Foundation-led 100 Resilient Cities Initiative.

College and university faculty, students, and researchers have been integral to many of these initiatives, yet it is unclear what kind of education or training these teams received to practice resilient design. This study, funded by the U.S.

Department of Homeland Security Science and Technology Directorate's Office of University Programs, fills the gap in our knowledge of how resilient design education is being delivered at U.S. colleges and universities across multiple design-related disciplines, including architecture, building sciences, engineering, landscape architecture, and planning.

This study seeks to understand the current state of training and education that is focused on resilient design. We employ mixed-methods, including an internet search, key informant interviews, case studies, and guidance and feedback from a review committee composed of experts across five disciplinary fields.

In this report, we review the concept of resilience as it relates to design, discuss the methods employed, and report the findings from our research which includes promising practices associated with the delivery of resilient design education. We conclude with a series of recommendations that suggest how to promote more robust education and training in resilient design at U.S. colleges and universities.

AN ORGANIZING CONCEPT


Photo Credit: Denniz Futalan

LITERATURE REVIEW

The concept of resilience, as applied to natural hazards and disasters, spans a range of perspectives, including those advanced by social scientists, engineers, land use planners, and others. Psychologist Fran Norris and her colleagues (2007) identified 21 different definitions encompassing the individual and community scales as well as social, ecological, and physical systems. In perhaps the most widely cited definition of disaster resilience, the National Academies defines resilience as "the ability to prepare for, absorb, recover from, and more successfully adapt to adverse events" (2012, p. 1).

Prior to the adoption of disaster resilience as an organizing concept, sustainability and disaster risk reduction (or hazard mitigation) provided primary conceptual frameworks used by policymakers and researchers to undergird professional practice and advance our base of knowledge (Beatley 1998; Burby 1998; Mileti 1999; Smith, Martin, and Wenger 2017). Sustainability and disaster risk reduction were used to frame a number of important international efforts, including the United Nation's International Decade for Natural Disaster Reduction in the 1990s; Agenda 21, adopted during the Rio Summit; and the 1994 Yokohama Strategy for a Safer World. Attempts to operationalize these broad multi-national efforts received heavy criticism from international development aid programs and disaster scholars for how the external assistance provided to the developing world failed to account for environmental impacts, social and cultural factors, local needs, locally-based site designs, and planning-related concerns due to exposure to natural hazards (World Commission on Environment and Development 1987; United Nations 1992; National Science and Technology Council 1996; Berke and Beatley 1995; Geis and Kutzmark 1995). In the most widely recognized definition of sustainable development, the Brundtland Commission referred to sustainable development as that which "meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987, p. 8).

During the 1990's, a Second Assessment of Natural Hazards knowledge was conducted, adding to our understanding of the growing field since the last assessment was completed in 1975. The text, Disasters and Design, emphasized "sustainable hazards mitigation," and applied the lens of sustainable development to our understanding of natural hazards and disasters (Mileti 1999). While the concept of disaster resilience was noted, it was framed as a subpart of the larger aim of achieving sustainable development and disaster risk reduction. Situating disaster resilience as a subcomponent of sustainable development has been discussed for some time, including, in particular, how planning can help to achieve this aim (Godschalk, Kaiser, and Berke 1998; Godschalk et al. 1999; Beatley, 2009; Berke and Smith 2009; Smith, Martin and Wenger 2017 pp. 596-600).

Planning scholars have produced a number of important strains of thought regarding resilience, including broader themes of flexibility, adaptability, and durability (Beatley 2009, p. 3). David Godschalk encapsulates this in his far-reaching definition of resilience:

> *Resilient cities are constructed to be strong and flexible, rather than brittle and fragile. Their lifeline systems of roads, utilities, and other support facilities are designed to continue functioning in the face of rising water, high winds, shaking ground, and terrorist attacks. Their new development is guided away from known high hazard areas, and their vulnerable existing development is relocated to safe areas. Their buildings are constructed or retrofitted to meet code standards based on hazard threats. Their natural environmental protective systems are conserved to maintain valuable hazard mitigation functions. Finally, their governmental, nongovernmental, and private sector organizations are prepared with up-to-date information about hazard vulnerability and disaster resources, are linked with effective communication networks, and are experienced in working together.*
>
> *– David Godschalk (2003, p. 137)*

This broad definition not only spans physical, social, and environmental dimensions, it also highlights areas where the design disciplines are uniquely positioned to offer assistance. This includes the role of engineers relative to infrastructure and critical facilities, landscape architects and land use planners regarding environmental stewardship and designing in a way that respects nature and natural processes, architects and building science officials addressing the issues tied to codes and standards, and the need for all disciplines to engage broad networks and foster good governance.

The application of disaster resilience began in earnest in the United States following the September 11, 2001 terrorist attacks. Furthermore, following Hurricanes Katrina, the Rockefeller Foundation incubated the idea of resilient recovery through their financial support and long-term commitment to rebuilding New Orleans through public/private partnerships, capacity building efforts, and technical assistance. The Mississippi Renewal Forum, which involved several hundred New Urbanists, focused on developing form-based redevelopment design plans for 12 communities devastated by Hurricane Katrina. Following Hurricane Sandy, the lessons learned from Katrina were used to guide the Rebuild by Design competition, a collaborative effort between the Rockefeller Foundation and the U.S. Department of Housing and Urban Development. The Rebuild by Design competition involved multi-disciplinary teams made up of architects, landscape-architects, engineers, scientists, social scientists, and water experts, who created proposals emphasizing innovative resilient design infrastructure projects (www.rockefellerfoundation.org).

The damage and destruction from disasters over the last two decades have elevated the call for more resilient design. Evidence of the demand for resilient design is reflected in the growth of curricular offerings within U.S. colleges and universities, which have also added capacity through new faculty lines, cluster hires, centers and institutes, and initiatives focused on resilient design. It is time to take stock of how we deliver resilient design education and assess the goals we have for educating future scholars and practitioners.

HOW TO IMPROVE DESIGN-BASED RESILIENCE EDUCATION

Disaster resilience has become a widely accepted aspirational goal across design professions, scholars, and educators, yet there has not been an examination of the type of education and training that students receive that make them sufficiently capable of reaching this goal. Moreover, how does our education system teach students to systematically address one of the most pressing issues of the 21st century, which is how do we design disaster resilient communities in an era of climate change, to include the rising costs associated with disasters? (Westcoat and Khan 2011; Smith 2014). Orr (1992) suggests that a different type of educational experience is needed in order to teach students how to address sustainability and resilience-related challenges in an era of climate change given their unprecedented complexity, emphasizing civic engagement and ecological literacy. As part of a larger systems approach to leaning, Honwad et al. (2014) suggests that teaching students about adaptation and building resilience requires students to learn: (a) how to make sustainable decisions (Atran, Medin and Ross 2005); (b) how to anticipate problems (Hewson 1992); (c) how to work within informal and formal environments (Bell et al. 2009); (d) how to understand and resolve complex issues (Resnick and Wilensky 1998); (e) how to appreciate varied cultures (Banks, et al. 2007); (f) how to resolve problems (Hmelo-Silver, Marathe and Liu 2007); and (g) how to collaborate with each other (O'Donnell, Hmelo-Silver and Erkens 2013) to build a sustainable and resilient future.

In order to achieve these and other aims noted above, how do we assess and operationalize whether disaster resilient design education and the implementation of these ideas is making a difference, both in terms of the number of appropriately educated students and whether the concepts, tools, and techniques taught are leading to more resilient structures, communities, regions, ecosystems, economies, and the larger global community? The first step in this process is to provide an assessment of the state of the knowledge on resilient design education across design disciplines, which is the primary purpose of this report.

METHODS

INTENT OF STUDY

The primary purpose of this report is to understand the current delivery of resilient design education across five design-related disciplines: architecture, building sciences, engineering, landscape architecture, and planning. There may be other disciplines that touch upon the topics of resilience and design, such as public health and sociology, but design is not a primary feature of these disciplines. As such, we limited our study to the five disciplines that are most engaged with resilient design in the academy and practice. The methods used in this research involved an extensive internet search of resilient design curricula, key informant interviews, consultation with a review committee consisting of experts across the five different disciplines, and case studies of resilient design educational opportunities.

INTERNET SEARCH

During the initial phase of researching online curricula related to resilient education, we did not limit the search to U.S. college and university curricula, but instead cast a wide net to better determine the varied ways in which resilient design education was being offered. The results of the U.S. view are shown in Figure 1 and documented in Appendix A. While we list all U.S. programs that we found in Appendix A, we did not evaluate their quality at this stage in the research process.

This search identified a number of delivery methods and a growing list of opportunities outside of the college and university setting that professionals can use to learn about resilient design. For example, professionals can engage in this subject area through courses provided by the U.S. Federal Emergency Management Agency's Emergency Management Institute or through opportunities tied to professional associations, such as the American Planning Association, American Institute of Architects, and National Institute of Building Sciences. Depending on the delivery method, professionals may be further incentivized by the option to receive continuing education credits and certificates focused on resilient design. Further, professionals seeking resources on resilient design can attend seminars, conferences, or workshops that are increasingly providing instructional materials on this topic.

In addition to professional opportunities, there are a wide number of disciplines that offer educational opportunities in resilience-thinking, such as those grounded in the social sciences and emergency management, that we were not able to explore at this time because they did not feature a strong design emphasis. Revisiting professional opportunities and U.S. college and university programs operating outside of the realm of design education would be a worthwhile endeavor for future research. However, after documenting the results of this initial internet search, we narrowed the scope of this study to educational and training opportunities at U.S. colleges and universities which prioritize design.

Within U.S. colleges and universities, five design disciplines offer resilient design education through courses, studios, disciplinary concentrations and specializations (which are typically a set of courses), and degree programs. Additionally, a large number of research centers and institutes within U.S. colleges and universities offer students resilient design learning opportunities through research assistantships, research fellowships, employment opportunities, internships, summer learning opportunities, and REUs (research opportunities for undergraduates). The learning opportunities at centers and institutes are often project-based or applied. Extension programs, which may be independent of academic units or organized within a department, also offer a number of resilient design learning opportunities through courses and applied research projects.

In the next phase of the research, we conducted a narrower but deeper examination into the five design-related fields. We searched for resilient design curricula and educational opportunities at U.S. four-year colleges and universities using a nested set of keyword searches. As shown in Figure 2, we searched across each discipline to identify institutions that offered resilient design curricula or educational opportunities. Next, we searched for the different delivery methods that these institutions provided, including within academic units (e.g. courses, studio courses, concentrations, specializations, certificate programs, and degree programs), in research centers and institutes, and through extension programs. Finally, we added keywords related to different types of hazards to the other search terms. For example, we added "Hurricane +

Figure 1 : Resilient Design Education Delivery Methods

RESILIENT DESIGN EDUCATION

Colleges and Universities

Traditional
- *Courses*
- *Studios*
- *Concentrations*
- *Specializations*
- *Certificates*
- *Degree Programs*

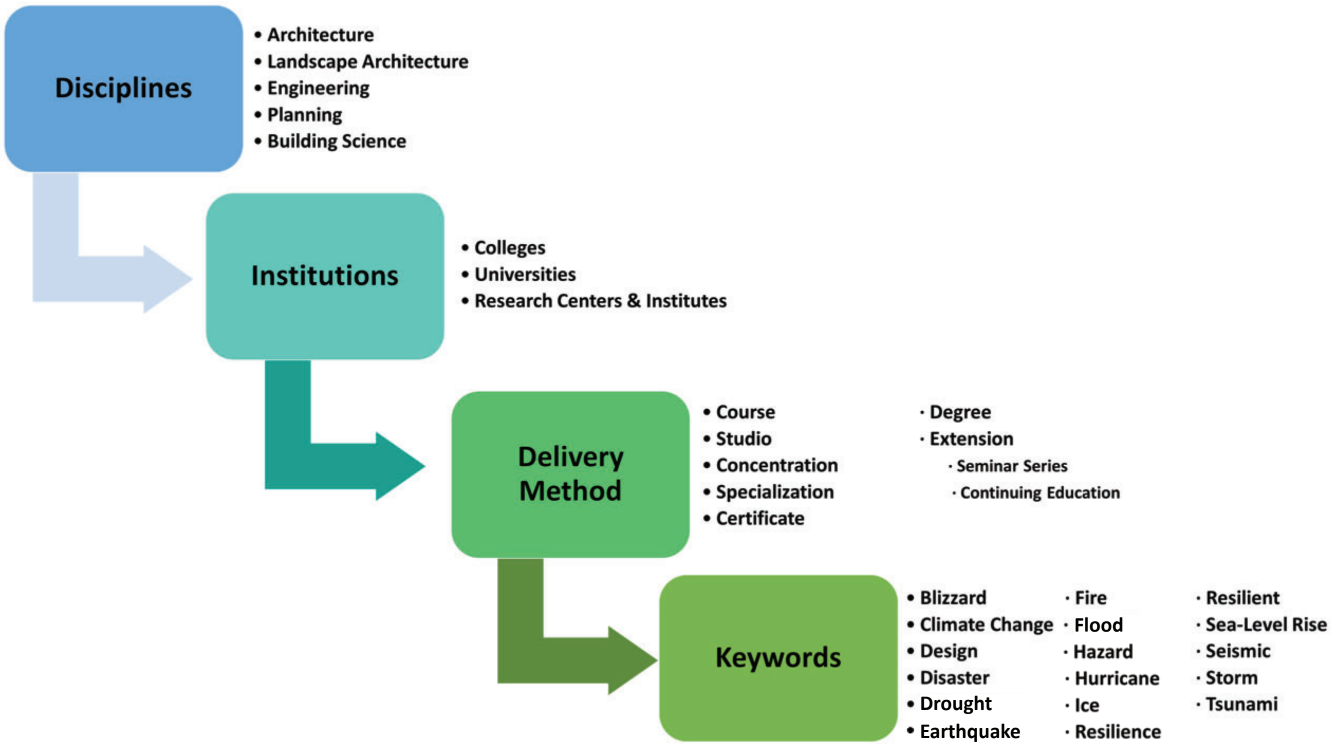
Research Centers and Institutes
- *Research Assistantships*
- *Summer Learning Opportunities*
- *Fellowships*
- *Student Jobs*
- *Internships*
- *Research Experiences for Undergraduates (REUs)*

Extension Programs

Professional Associations

Education and Credentials
- *Continuing Education Courses / Credits*
- *Webinars*
- *Professional Certificates*
- *Seminar Series*
- *Conferences*
- *Workshops*

Figure 2: Keywords Used in internet Search of Resilient Design Education



Center" to determine whether each college or institution had a hurricane center. Once we identified resilient design educational offerings, we cataloged and reviewed them to develop an understanding of how resilient design education is delivered.

KEY INFORMANT INTERVIEWS

Using a snowball sample, we identified experts in each of the five disciplines with whom we conducted phone and in-person interviews. Interview participants were initially recruited via email and asked to participate in a 30-60 minute semi-structured interview. The interview instrument included two sections – general questions and discipline-specific questions. First, a series of nineteen "general" queries was used to elicit knowledge of resilient design education generally and as it relates to the interviewee's specific discipline. This was followed by a set of queries focused on the prevalence, type, and quality of resilient design instruction, tailored to the discipline of the interviewee.

Two interviewers participated in each conversation with informants, with one person typing up the verbatim responses. The notes were then coded deductively and inductively for common themes pertaining to the definition of resilience, how resilient design education is delivered, and the challenges associated with teaching and training resilient design concepts. In total, 18 key informants were interviewed. For a list of interviewees, see Appendix B.

REVIEW COMMITTEE

A review committee comprised of 18 scholars and practitioners who are experts in the field provided guidance and feedback throughout the research process. In the early stages, the review committee identified programs that provide resilient design education and offered the research team an interdisciplinary perspective. The review committee also provided feedback on the initial coding of interviews, preliminary research findings, and the first draft of the written report. We convened the advisory panel twice via Webex, a video conferencing tool that allows for the sharing of slides. For a list of review committee members, see Appendix C.

CASE STUDIES

After conducting the internet search, key informant interviews, and consulting with the review committee, we identified innovative examples of programs or academic units that deliver resilient design education across the various disciplines included in this study. We conducted case studies of California Polytechnic State University, San Luis Obispo; Louisiana State University; North Carolina State University; and Texas A&M University. To develop these case studies, we reviewed written material about these programs, interviewed knowledgeable faculty and staff, and received feedback from faculty and/or staff on the initial draft of the case study to ensure that our analysis was accurate.

RESULTS

Project Credit: Zixu Qiao, Texas A&M University

Resilient design is a small but rapidly growing area of study. It is taught at the undergraduate, Master's, and PhD levels. Engineering offers numerous courses in resilient design, but that is partly due to how engineers define resilient design – resilience is a standard of design, construction, and/or development that is guided by industry performance standards. Thus, it is argued by many of those in the profession that all engineering products/structures/systems are resiliently designed if they meet industry standards. Whether this is an accurate statement is subject to debate, particularly as we enter an era of climate change. These types of industry standards are also present in the field of building sciences. Other fields, such as architecture, landscape architecture, and planning, that have a much broader definition of resilient design have fewer course offerings on the topic.

Further evidence of the nexus between resilience and design includes the growing number of individual courses taught as well as the creation of university degree, minor, and certificate programs. The growing focus on natural hazards, disasters, and resilient design in college and university curricula, while promising, remains highly varied. Resilient design courses and programs are frequently siloed in particular disciplines rather than serving as a venue to apply interdisciplinary systems thinking. Similarly, the majority of courses are developed in isolation rather than as part of degree, minor, or certificate program. Although, this appears to be changing with the advent of new curricula addressing this shortfall.

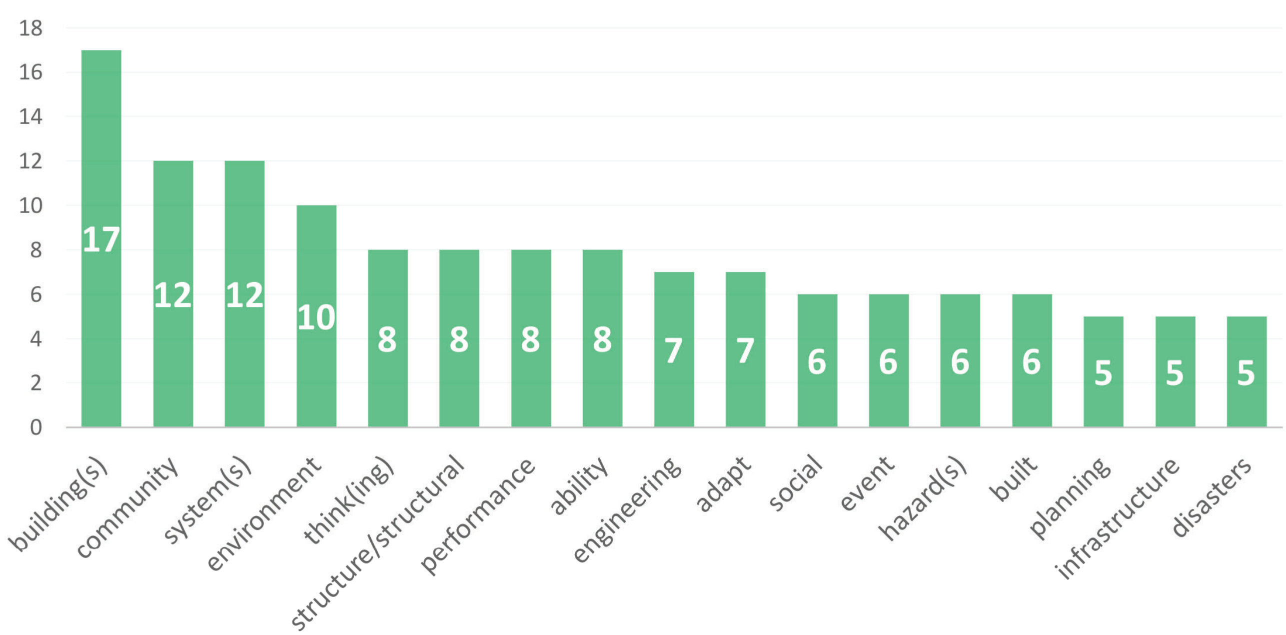
Resilient design education curricula are often driven by the passion and interests of an individual faculty member who teaches a course or studio. Studio courses – usually offered in the architecture and landscape architecture disciplines, and to a lesser extent in the planning discipline – involve an applied problem or project and may be client-based. Studios can be used to foster inter- and multi-disciplinary experiences for students and faculty.

Beyond curricula within academic units, including studio-based examples, research centers, institutes, and extension programs offer students project-based or experiential learning about resilient design. These are spaces in which inter- and multi-disciplinary collaborations between faculty, students, and practitioners can take place through funded research or applied resilient design projects.

INTERNET SEARCH RESULTS

The internet search revealed a highly varied set of curricula and university offerings on resilient design. The subject matter is one that is new, yet growing very rapidly. Since we began this study in October 2016, there has been a noticeable increase in faculty hires and curricula related to resilient design. For example, The Graduate School of Architecture, Planning and Preservation at Columbia University is currently hiring up to three Associate Research Scholars in Resilient Design and Planning and recently established a new Center for Resilient Cities and Landscapes (CRCL). This center will collaborate with staff from 100 Resilient Cities and work around the world with communities to enhance their resilience. In addition, there are a number of universities, including the University of Hawaii and the University of Florida that announced cluster hires in the area of resilient design. In 2017, the College of Design, Construction and Planning (DCP) at the University of Florida announced that they would be accepting applications for up to four open-rank tenure-track faculty positions as part of a major new initiative to build on their design, construction, and planning expertise in the area of "Resilient, Smart, Sustainable and Healthy Built Environments." Recently, the University of Delaware announced that they will search for a cluster of five interdisciplinary faculty in the area of disaster science and education in the fall of 2018. The disciplines that would be suitable for this cluster hire include: public health, social science, environmental risk, crisis informatics, and civil engineering. Further evidence of this trend is represented by Clemson University's new Master's degree in resilient design. The first cohort of students was admitted in the fall of 2018 at the Charleston, South Carolina campus. These examples, and the case studies found throughout this document show that there is increasing interest in developing curricula at the intersection of resilience and design.

Figure 3: Word Frequency, Resilient Design Definition



INSIGHTS FROM KEY INFORMANT INTERVIEWS AND ADVISORY PANEL

In the following section, we analyze the qualitative key informant data and consult our review committee to examine differences across disciplines in how resilient design education is viewed, but also whether there were common themes that cut across the five disciplines. Both the key informants and the review committee are experts in their respective fields. They include faculty, research scientists, and practitioners.

DEFINING RESILIENT DESIGN

First, we asked experts across the five disciplines to define the concept of resilience. Their responses show that the most frequent words used to define resilience include buildings, community, systems, and environmental (Figure 3).

The experts' definitions of resilience were also indicative of the evolution of the concept. Interviewees across disciplines agreed that resilient design is systems-based, multi-scalar, and requires interdisciplinary thinking. Resilient design requires a systems-based approach because of the interdependencies embedded within and between the ecological, physical, and social environments. These ideas are illustrated by the following statement:

> *"It is not just building by building or structure by structure, but it is looking at the systems of buildings, housing, commercial, government, culture, infrastructure, and saying, 'well what do we have to do to design these to be resilient?'"*
>
> *– Dr. Mary Comerio, Department of Architecture, University of California, Berkeley*

A resilient system also takes into account multiple scales of vulnerability and risk. Furthermore, many systems' domains lie within particular scales. A water system can be regional or national while a building's system is site specific. While both systems are indicative of drastically different scales, they are interdependent. Considering how to develop more resiliently at multiple scales is more commonly addressed in the fields of planning and landscape architecture than in architecture, building science, or engineering. The following two statements from an urban planner and landscape architect address the multi-scalar concept:

> *"We articulate it in such a way that we have significant chunks of the curriculum spent on the urban scale, over all human settlement, the MSA [Metropolitan Statistical Area], and then you have the neighborhood scale..."*
>
> *– James Spencer, Department of City and Regional Planning, Clemson University*

> *"It can almost be anything so you have to define the scope and scale of what you are looking at. Large riverine systems and greenways [are] so regional, but [resilient design] can be all the way down to a school yard, a very small urban school that uses the rainwater."*
>
> *– Andy Fox, Department of Landscape Architecture, North Carolina State University*

While many of the interviewees across disciplines agree that resilient design should be systems-based and multi-scalar, within the university setting, the delivery of resilient design curricula is often siloed and focuses on a limited scale and system. As a consequence, students in design related disciplines are often unexposed to resilient design from a systems-based and multi-scalar perspective. Architecture, building sciences, and engineering tend to have a narrower focus on specific scales within their curriculum. One engineer highlights these limitations within the discipline:

> *I think we need to go to a broader look to see how the building fits into a system, and I think this is true for building sciences as well, but we need to start making linkages.*
>
> *– Terri McAllister, Engineer, National Institute of Standards and Technology*

Among the engineering interviewees, there was a commonly shared view that as a profession, their goal is to always design resilient structures. What this suggests is that the field of engineering uses performance standards to ensure that what is designed and built can withstand shocks to a given design standard and return to a steady-state equilibrium. These performance standards are foundational to engineering education and are integrated into departmental accreditation standards at U.S. colleges and universities as well. However, performance standards are not necessarily adjustable or flexible, thus limiting the ability to respond to unexpected shocks, such as those created by extreme and intensifying weather events. This is evident in the emerging challenges associated with the use of the concept of stationarity (i.e. relying on past hazard history to establish design parameters) in an era of climate change, whereby such standards are now viewed as insufficient.

THE EVOLUTION OF RESILIENCE AS A CONCEPT

The concept of resilience has historically focused on technical resilience. More recently, resilience has come to encompass social dimensions, dynamic processes, and multidisciplinary perspectives, as explained here:

> *Initially, [it was] strictly technical... At first it had little to do with the knowledge of people and how communities work... It's moved toward finding some balance between that [nonhuman physical resources and systems] and people.*
>
> *– Kofi Boone, Department of Landscape Architecture, North Carolina State University*

This evolution of the concept has altered the way in which resilient design is taught, incorporating not only built or natural systems, but also considerations about social vulnerability, equity, organizational/institutional capacity, political factors, and power dynamics in shaping a community's ability to be resilient. The findings from our study show that more recently, disciplines that were rooted in building resiliently through the built environment, such as engineering, have recognized the importance of cross-disciplinary perspectives. One civil engineer remarks:

> *I think there's been much more emphasis on the non-engineering aspects of resilience. For example, considering social resilience, community preparedness, the non-engineering aspects.*
>
> *– Reginald DesRoches, School of Civil and Environmental Engineering, Georgia Institute of Technology*

INTER- AND MULTI-DISCIPLINARY PERSPECTIVES

The organizational structure of U.S. colleges and universities creates substantial barriers to providing educational experiences that allow students to learn how to work in inter- and multi-disciplinary teams and to understand the systems-based and multi-scalar nature of resilient design beyond their own discipline. This sentiment is expressed here:

> “*The problem is that academia is very siloed and doesn't bring together the disciplines as it should. When you work in the real world, it is interdisciplinary.*”
>
> *– David Vaughn, Department of Civil Engineering, Clemson University*

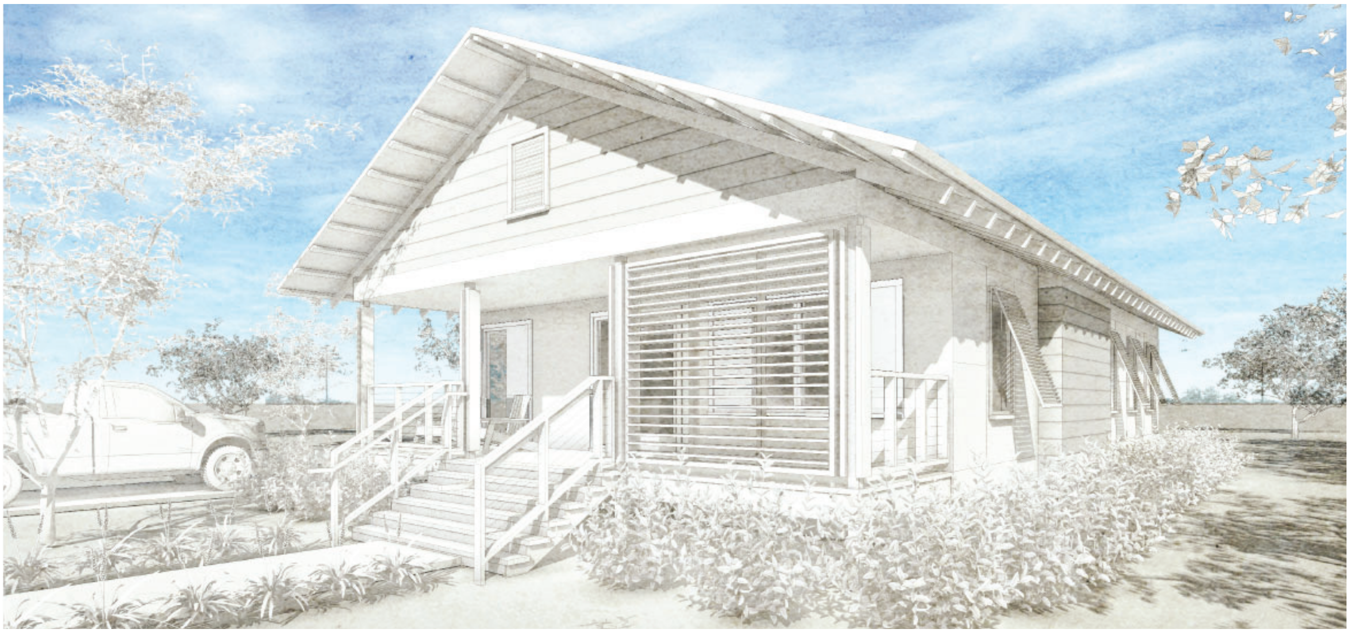
The interview data reveal that the most common form of interdisciplinary teaching involved studio courses, which are most often delivered in architecture, landscape architecture, and to a lesser extent, planning programs.

> “*In educational settings, it's studios or research projects that are interdisciplinary.*”
>
> *– Kofi Boone, Department of Landscape Architecture, North Carolina State University*

To learn more about how interdisciplinary studios can offer valuable student learning opportunities, we turn to the example of North Carolina State University's unique approach to resilient design education. While multiple faculty members push interdisciplinary work in the classroom, their Coastal Dynamics Design Lab offers opportunities to connect this interdisciplinary thinking to applied projects, including design charrettes.

CASE STUDY 1

NORTH CAROLINA STATE UNIVERSITY | COLLEGE OF DESIGN: MASTER OF LANDSCAPE ARCHITECTURE



The drawing, created as part of the Hurricane Matthew Recovery and Resilience Initiative (see p. 30), shows a conceptualization of a house elevated above flood levels using a design style familiar to the local context. It is part of a series intended to provide replacement housing options for those who are participating in the post-disaster program that acquires and demolishes one's home and commits the land to open space in perpetuity.

North Carolina State University's landscape architecture program approaches resilient design from a systems-thinking and multi-scalar perspective, incorporating both engineering and architecture in many of its studios and classes. According to Andy Fox, an associate professor in Landscape Architecture, landscape architects work across a range of scales that can be as small as a school yard and as large as a region.

NC State teaches students to conceptualize a variety of landscape scales as well as the systems they are entangled in from a resilience perspective. Kofi Boone, Associate Professor of Landscape Architecture, describes how the discipline is uniquely suited to focus on multiple scales especially when dealing with water systems:

> *"Across the discipline, it's multi-scalar… you have to deal with water at multiple scales. You can't stick to one scale."*
>
> *– Kofi Boone, North Carolina State Landscape Architecture*

RESILIENT DESIGN COURSEWORK

In addition to being multi-scalar and systems based, NC State also incorporates architecture and engineering into landscape architecture studios. This serves as the primary means by which NC State exposes students to other disciplines. Students are also involved in design studios that focus on problem-based learning and are largely student driven with faculty reviews rather than more traditional settings like seminars or labs. Studio-based classroom opportunities provide students with an understanding of other disciplinary perspectives on resilient design. One drawback, however, is the reliance on individual faculty to push interdisciplinary work in their teaching spaces. This is not a sustainable model for delivering interdisciplinary training, but should be embedded and institutionalized in the curriculum.

> *"We do it in our coursework, but there is nothing in our program. We don't do this as a program objective."*
>
> *– Andy Fox, NC State Landscape Architecture*

Students can cross-enroll in engineering, landscape architecture, and architecture at NC State. One example involves students working in bio-agricultural engineering and landscape architecture, cross-enrolling because of a common focus on stormwater management. There has also been success in integrating this type of engineering with landscape architecture principles in seminar and studio courses.

While students are able to pursue concurrent degrees at NC State, this is not supported by an official "dual degree" program offered by the school. NC State's architecture and landscape architecture programs allow for some overlap between the two degree's course requirements which means that some classes count toward both degrees. Additionally, some classes can be modified, or even waived from one curriculum if the student provides evidence that a topic is being covered to acceptable standards in another program, thereby offering some flexibility. Students have also focused on resilient design through the Coastal Dynamics Design Lab (CDDL) and completed dual degrees.

COASTAL DYNAMICS DESIGN LAB (CDDL)

The Coastal Dynamics Design Lab (CDDL) connects interdisciplinary coursework with applied, real-world challenges. Founded in 2013, the CDDL is geographically oriented towards environmentally vulnerable towns on the Mid-Atlantic seaboard, with projects focused on how to increase community resilience in the face of natural hazards and climate change-related risks. Its mission is to lead multidisciplinary research and design teams that are created to address ecological, social, and physical challenges in these communities. Teams consist of landscape architects, engineers, architects, and graphic designers. The Lab is co-taught by a Professor of Architecture, David Hill and an Associate Professor of Landscape Architecture, Andy Fox.

The CDDL provides an advanced course opportunity (summer seminar) for students, but also serves as a component of other classes by bringing students into projects the Lab supports. Students in the advanced course are involved with all aspects of research, teaching, and engagement. These activities are carried out through coursework (registered students in the classroom) and funded graduate positions.

The CDDL offers three and six credit-hour courses to graduate students across the academic year and a Coastal Dynamics Summer Seminar. On average, 20 students (predominantly from departments of landscape architecture and architecture) are enrolled in CDDL courses. The Lab employs about four graduate research assistants each year, engages licensed professionals, and partners with other universities such as East Carolina University's geography program and the University of North Carolina at Chapel Hill's Coastal Resilience Center of Excellence. To date, 18 students have worked as research assistants at the CDDL.

Tackling applied challenges is a priority of the CDDL. NC State students have been involved in two design charrettes related to Hurricane Matthew recovery in eastern North Carolina. The first charrette was held in January of 2017, three months after Hurricane Matthew struck. DesignWeek involved students and faculty from the departments of Landscape Architecture and Architecture in the College of Design at NC State and the Department of City and Regional Planning and the Hurricane Matthew Disaster Recovery and Resilience Initiative at UNC-Chapel Hill. The purpose of the event was to develop preliminary designs to increase North Carolina community resilience to future flooding in three communities. The work was divided between interdisciplinary student teams that brought a diversity of experience and expertise. The charrette forced students to use their various skill sets in a collaborative setting and develop a common vision for each community. Student teams were also required to present their findings and associated designs to local officials from the impacted communities as well as a review panel comprised of design faculty and professionals.

The second charrette occurred in August of 2017 and involved architects; landscape architects; planners; engineers; emergency managers; federal, state, and local officials; and students from NC State and UNC-Chapel Hill. The purpose of this charrette was to conceptualize the future of Princeville, NC, the first town established by freed enslaved people after emancipation in 1865. Princeville was hit especially hard by Hurricane Matthew, with the majority of its residents unable to return to their homes more than one year after the event. The charrette allowed students to work in a high-pace, high-stakes environment with professional interdisciplinary teams that considered not only design but policy, regulations, and the future resilience of the town's residents.

Disciplinary diversity is not required in the curriculum of either NC State or UNC, Chapel Hill. Efforts to diversify subject matter were driven by the actions of faculty who agreed to work together following Hurricane Matthew. Due to the efforts of several engaged faculty at NC State, a resilient design curriculum has been developed that is focused on providing students applied training that spans systems, is multi-scalar, and advances interdisciplinary perspectives through studios, classes, and design charrettes.

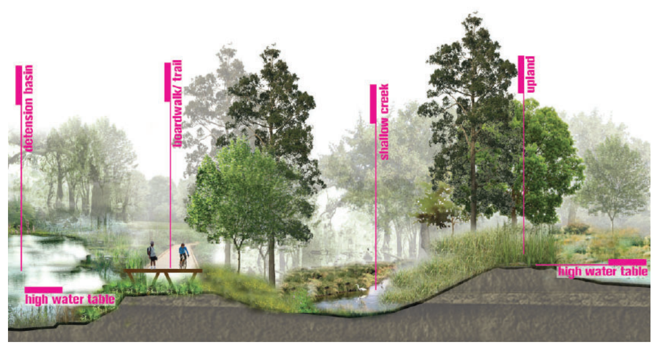


Diagram from a winning DesignWeek project: 'Eat Drink Play | Kinston'

CENTERS AND INSTITUTES

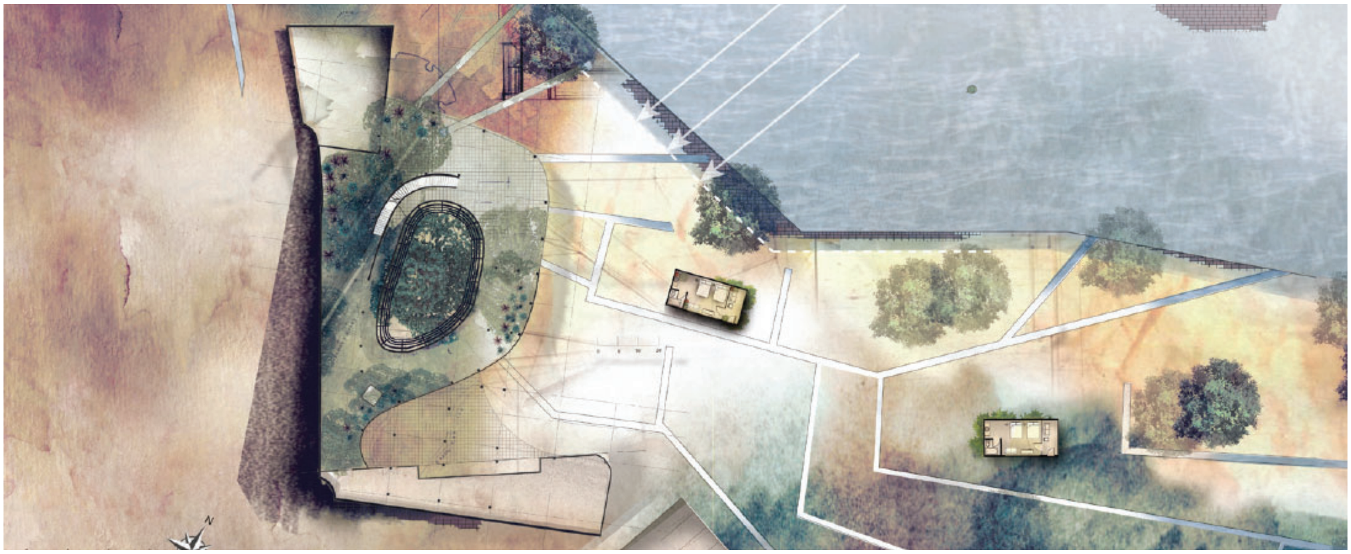
Beyond the classroom, students are often exposed to resilient design projects through work at university affiliated centers and institutes. These centers and institutes attract research and contract funding that often facilitates collaborations among an interdisciplinary group of faculty and students. Our interview data reveal that research centers and institutes may be the most fruitful unit within the academy to fund, facilitate, and encourage inter- and multi-disciplinary resilient design collaborations, thereby providing rich learning opportunities for students. In addition, applied or client-based projects that are often run through centers and institutes provide experiences for students that more closely resemble resilient design in practice. These experiences have lasting education impacts on students, as explained below:

> “*With the [Pacific Earthquake Engineering Research Center], you did interdisciplinary work and students worked in those interdisciplinary teams… [I]t changed the culture of the way engineering students learned how to work…they developed these relationships and bonds that are lasting 10-15 years after the center…I think that culture change has had a significant impact.*”
>
> *– Mary Comerio, Department of Architecture, University of California at Berkeley*

In two case studies, Louisiana State University and California Polytechnic State University, San Luis Obispo, we discuss the opportunities for student learning through studios, centers and institutes, and applied projects.

CASE STUDY 2

LOUISIANA STATE UNIVERSITY | INTERDISCIPLINARY: DESIGN, ENGINEERING, ENVIRONMENTAL



A rendering shows a site plan developed within the Grand Isle Studio, which focused on designing for a disappearing and changing landscape in southern Louisiana. Studio Instructor: Elizabeth Williams; Credit: Abbey Brown

Louisiana State University's location near the Lower Mississippi River Delta is central to the development of their coastal resilience and sustainability focus. Multiple units on campus, including the College of Art and Design, the College of Engineering, and College of the Coast and the Environment contribute to an interdisciplinary and robust resilient design education spanning undergraduate to PhD students. These units examine: 1) changes to the deltaic system, 2) how human actions can mitigate the negative consequences of development and climate change, and 3) how to think about the future of human settlement in at-risk areas.

COASTAL SUSTAINABILITY STUDIO

The Louisiana State University Coastal Sustainability Studio (CSS) is an interdisciplinary program that involves the College of Art and Design, the College of Engineering, the College of the Coast and Environment, the College of Science, and the College of Humanities and Social Sciences. Founded in 2009, the CSS seeks to connect disciplines that often work separately to develop creative, comprehensive strategies to respond to coastal challenges. Jeff Carney, an Associate Professor of Architecture and former Director of the CSS, explains that the studio is a way for students to use a systems approach to think about different scales of resilience outside of their individual disciplines. For example, landscape architects are more engaged in systems and larger scale implications of changes to the landscape than architects, who usually focus on the design of an individual site or building. As an interdisciplinary studio, students can expand their ability to think on multiple scales.

In contrast to NC State's Coastal Dynamics Design Lab (see case study on page 18), opportunities to work with the studio are available primarily through assistantships with limited course related options. The CSS offers graduate assistantships and summer internships for students as a means to complement research interests outside of the classroom. The CSS is less embedded in the curriculum but often supplements traditional academic course work. Since 2009, the CSS has employed between five to fifteen students per academic year and between three to twenty students as summer interns.

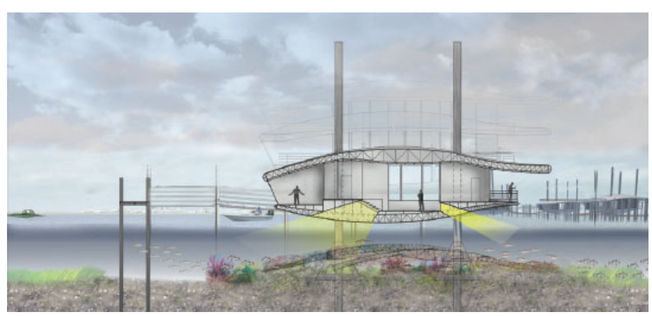
COASTAL STUDIES INSTITUTE

The Coastal Studies Institute (CSI) evolved from a postwar concern over the lack of coastal environmental data that could be used to predict coastal conditions and the need to understand the world's coastlines for national security and defense purposes. The CSI was founded in 1952 and recognized by the Louisiana State Board of Supervisors in 1954 when it became an independent unit of the School of Geoscience. Its mission today is to facilitate the development and integration of coastal science and engineering expertise to inform policies that promote environmental sustainability of the Mississippi River Delta and deltaic coasts around the world. Their mission is focused on the enhancement of research and educational opportunities in coastal regions.

CSI currently involves 29 faculty representing the fields of engineering, oceanography, geography, anthropology, geophysics, and geology; 59 PhD and post-docs; 45 master's students; and seven undergraduates. The CSI includes multiple disciplines with separate labs for specific fields of research, such as the Coastal Morphodynamics Laboratory (CML), the Marine Meteorology Group, and the Earth Scan Laboratory (ESL). While the interdisciplinary research conducted to understand coastal dynamics is crucial to planning for present and future coastal issues, there is little mention of applying these findings in design related projects such as those undertaken by the CSS, although this appears to be changing. One way the CSS and CSI are working together is through a partnership focused on a Delta Research Minor, with additional support from LSU's engineering and design schools, as well as the Office of Research and Economic Development.

UNDERGRADUATE MINOR: DELTA RESEARCH

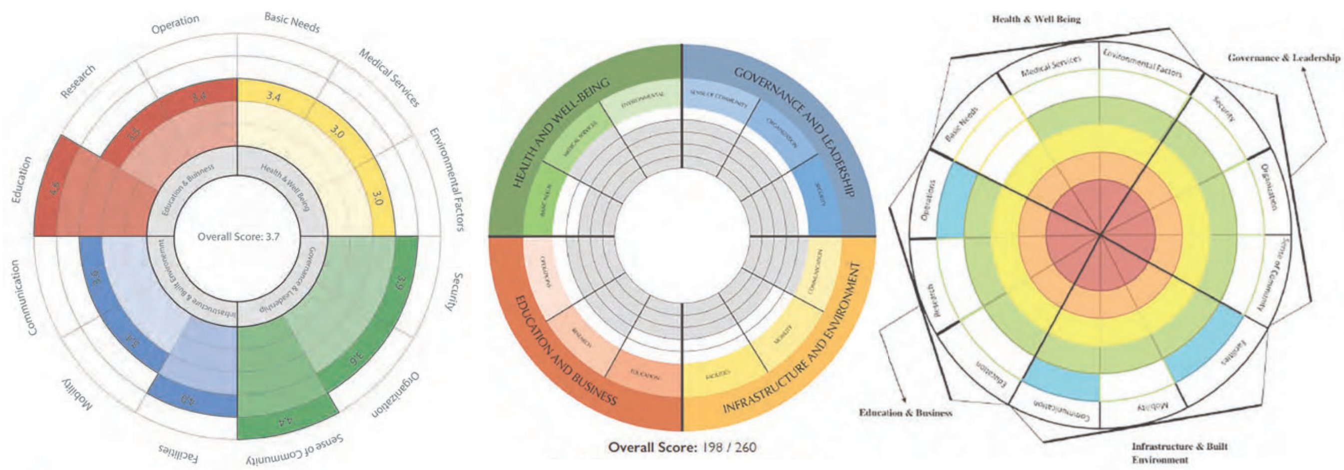
LSU is developing an interdisciplinary undergraduate water-intensive minor built around a collaborative approach emphasizing "design thinking." The proposed multi-disciplinary undergraduate Delta Research Minor will focus on coastal issues with distinct but interrelated scientific, engineering, and design components. In collaboration with CSI and ORED (Office of Resarch and Economic Development), and the Colleges of Art + Design, Coast and Environment, and Engineering, CSS led the effort to launch the program. The Delta Research minor includes the following components: multidisciplinary and faculty-mentored research, including field research at the Louisiana Universities Marine Consortium; access to the Delta Research Studio, a new active learning environment; and participation and presentations within a symposium framework. Graduates of the 15-hour program will be uniquely prepared to face the complex challenges facing coastal Louisiana and similarly vulnerable coasts worldwide.



Grand Isle Studio; Studio Instructor: Elizabeth Williams; Credit: Kyle Schroeder

CASE STUDY 3

CAL POLY SAN LUIS OBISPO | DEPARTMENT OF CITY AND REGIONAL PLANNING



Examples of Campus Resiliency Index (CaRI) wheel developed by groups of 3 students during a 5-week project in the 'Hazard Mitigation and Design: Towards Resilient Communities' course. The drawings incorporate fifty-three pieces of information used to measure holistic resiliency goals.

LEARNING BY DOING

The City and Regional Planning (CRP) Department at California Polytechnic State University, San Luis Obispo (Cal Poly) aligns with the university's motto "Discere Faciendo" or "Learn by Doing," and provides students with numerous opportunities to engage the world outside the classroom through the ideas learned through applied curricula. CRP stands out among programs in our investigation due to the heavy faculty workload in teaching both graduate and undergraduate students. Faculty teach a 3-3-3 schedule, meaning they lead three courses per trimester. Consequently, much thought has been placed on providing a resilient design education through classroom instruction and applied class projects.

CRP is home to the Resilient Communities Research Institute (RCRI). The institute is an interdisciplinary group of faculty, students, and practitioners "devoted to advancing the application of knowledge and practice that improves the quality and safety of the built environment." The experiences provided through applied coursework and working in interdisciplinary teams with on-going projects through the RCRI provides undergraduate and graduate students with rich opportunities for a resilient design education.

MEETING CALIFORNIA'S CURRENT PLANNING CHALLENGES

A defining feature of CRP is its connection to ongoing projects outside the university, engaging communities attempting to adapt to climate change. The department goes beyond traditional credit-granted coursework through the use of internships to provide a range of classes integrated with ongoing planning processes being undertaken by state and municipal governments grappling with hazard resilience. For example, an ongoing contract with the State of California's Office of Emergency Services enables graduate and undergraduate students, faculty, and practitioners to update the State Hazard Mitigation Plan every five years.

Cal Poly puts its students on the front lines of state planning initiatives through additional class projects, such as preparing comprehensive plan updates, local resiliency indices, and climate action plans. In 2008, when Cal Poly students developed the City of Benicia's climate action plan, the only other city in the state to have such a plan was San Francisco. The department's strong ties to industry partners, such as Arup, allow students and faculty to work alongside practitioners, thereby gaining experience from those already working in the field. In collaboration with Arup, the department developed campus resiliency index models and conducted campus resilience planning. The interaction with a private sector partner also fosters potential job opportunities upon graduation.

CRP hosts a biennial Climate Action Planning conference, which drew over 300 attendees in 2017 and provides another venue for students to make connections with professionals involved in resilience-related work. The event has been credited with building interest for students to take resilience-related courses. In 2018, a Resilient Design: State of the Art Symposium was held, where the leading design professionals assembled to establish what it takes to make the built environment more resilient, and how to advance a curriculum that supports resilience-thinking.

By embedding professional networks and applied and project-based learning opportunities in the curriculum, students pursuing a CRP degree at Cal Poly graduate with substantial cross-sectoral work experience that is attractive to employers. The department aims to equip graduates to understand resilient planning concretely through repeated case examples, studios, and practitioner-guided work.

'Amphibious Neighborhoods' by Amanda F., Iliana V., Elise A.; and Andres R., students in the Cal Poly Landscape Architecture Program

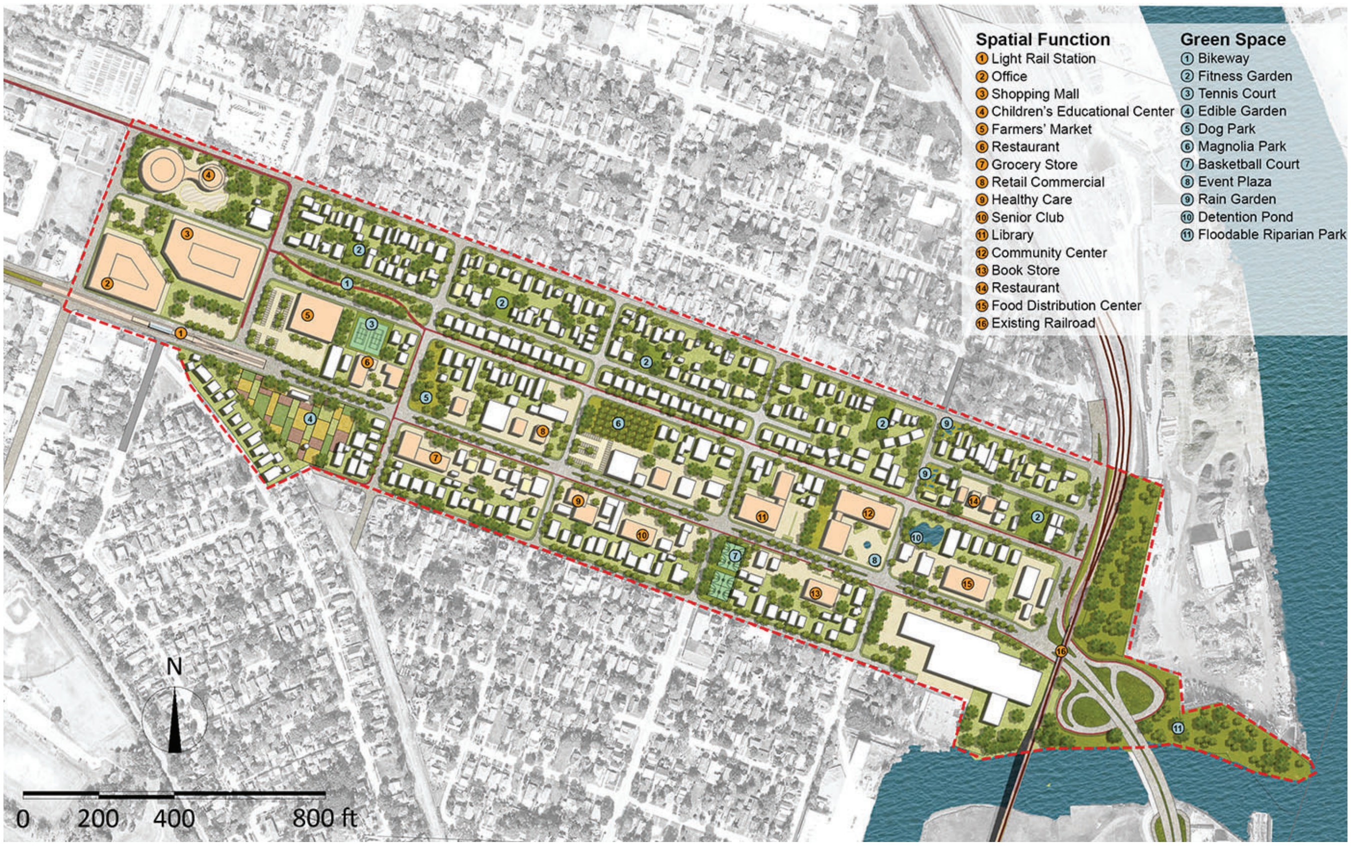
INSTITUTIONAL BARRIERS

There are real barriers to institutionalizing resilient design education that incorporates interdisciplinary perspectives, which often results in resilient design remaining on the periphery, rather than as a core element of the curriculum. Texas A&M University, identified in our study as having a wide number of resilient design learning opportunities through the curriculum, centers and institutes, and applied research projects, still struggles with the institutional barriers to teaching across disciplines as evidenced by the following comment:

> *"Universities don't like inter-disciplinary degree courses. They want it, but when it comes to implementing it, departments get concerned about compensation. There's tension, because people are always trying to keep their numbers up."*
>
> *– Phil Berke, Department of Landscape Architecture and Urban Planning, Texas A&M*

Texas A&M University is committed to breaking down the siloed disciplinary walls through its new Institute for Sustainable Communities. While the institute's mission is not framed around resilient design, but rather sustainability, the work at the institute is closely aligned with concepts relating to resilience. For more on Texas A&M, read the following case study.

TEXAS A&M UNIVERSITY | DEPARTMENT OF LANDSCAPE ARCHITECTURE AND URBAN PLANNING



A Master Plan study from 'Neighborhood Detox: Enhancing Resilience in a Hazard Vulnerable Area' by Yangdi Wang, a graduate student at Texas A&M University.

EXPANSIVE AND MULTI-DISCIPLINARY RESILIENT DESIGN CURRICULUM:

The Master of Urban Planning (MUP) degree program, which is housed in the Department of Architecture and Urban Planning at Texas A&M University showcases an expansive curriculum and multidisciplinary foci on resilient design through a center and an institute. The curriculum offers both a formal certificate program in Environmental Hazards Management and a program concentration in Resilient Communities. In addition to in-class learning, the program provides opportunities to work on multidisciplinary and applied projects through the Hazards Reduction and Recovery Center and the Institute for Sustainable Communities. The applied projects also connect students and faculty to practitioners and communities, thereby creating opportunities to be challenged with real life resilient design projects.

RESILIENT DESIGN COURSEWORK:

The program features six graduate-level course options, or 18 credit hours including: Analyzing Risk/Hazard and Public Policy, Disaster Recovery and Hazard Mitigation, and Organizational and Community Response to Crises and Disasters.

The Environmental Hazards Management (EHM) Certificate engages students in "a cross-disciplinary program that has been designed to provide students with an understanding of the interrelationship between the built environment, social systems, and extreme [natural, technological, or terror-related] environmental events." There are four tracks in the certificate program, including hazard mitigation planning, emergency management planning, environmental hazards management planning, and disaster health systems planning. The certificate emphasizes an interdisciplinary perspective, including at least three credit hours of required coursework to be taken outside the department. The organizational structure includes three dean-appointed faculty members who make up the EHM Certificate Council and serve in an advisory capacity.

RESILIENT COMMUNITIES CONCENTRATION:

In addition to the EHM certificate program, students can pursue a concentration in Resilient Communities, which is comprised of a 12 credit-hour set of courses. These courses are managed by eight faculty members and provide students an education in: land use and environmental planning, mitigation and recovery from natural hazards, sustainable urban communities, ecological systems, and the relationship between the environment and human health.

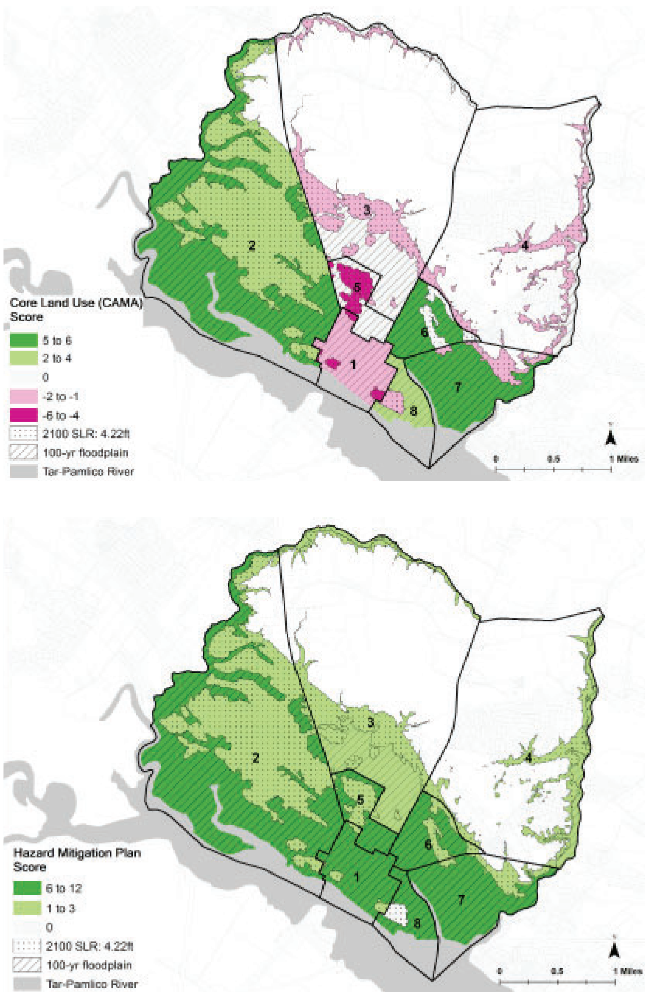
RESILIENT DESIGN PRACTICE:

Texas A&M prioritizes community engagement and participatory research at the Hazards Reduction and Recovery Center and the Institute for Sustainable Communities.

The Hazard Reduction and Recovery Center (HRRC), founded in 1988 by Dr. Dennis Wenger, focuses on an interdisciplinary approach to research and education in hazard analysis, emergency preparedness and response, disaster recovery, and hazard mitigation. HRRC employs architects, planners, sociologists, policy analysts, economists, landscape architects, and engineers. The HRRC's focus is on expanding the hazard research community by educating the next generation of leaders in the resilience field, engaging communities affected by hazards, and sharing research findings both within and outside the academy. The HRRC is unique in that it is a unit that reports to the Office of the Provost, despite being operated primarily by faculty in the Department of Landscape Architecture and Urban Planning. This organizational structure allows students and faculty who engage with the center to be exposed to interdisciplinary perspectives on disaster resilience.

The Institute for Sustainable Communities (ISC), directed by Dr. Philip Berke, brings together researchers and students from across the university to engage in transformative research that shapes the future of communities. The Institute offers opportunities for cross-disciplinary learning and collaboration on projects that relate to resilience. A recent project involved teaching communities how to use land use planning to reduce damage from natural hazards. Specifically, the ISC developed the Plan Integration Resilience Scorecard that identifies hazard zones as well as physical and social vulnerabilities while evaluating the degree to which a community's existing plans reduce or exacerbate exposure to natural hazards.

Texas A&M offers expansive and multidisciplinary opportunities in resilient design education, supplying students with multiple pathways to engage in scholarship and practice. Even with these options present, resilient design instruction is not a central part of the core curriculum in any of the three departments within the College of Architecture, including planning, landscape architecture, and architecture. Texas A&M is not alone in this curriculum arrangement and there are very few programs in the U.S. that teach resilient design within the core curriculum.



Plan integration maps identifying the vulnerability of different areas in the context of land use and municipal planning. Credit: Jaimie Masterson and Phil Berke, Department of Landscape Architecture and Urban Planning, Texas A&M University.

CHALLENGES IN IMPLEMENTATION

Our interviews revealed that the delivery of resilient design education is often the result of one leader or champion. Relying on the efforts of an individual or small group is not sustainable and will likely not continue if that leadership leaves the institution. We found this to be true across the disciplines, as explained below:

> *It always ends up being about the personalities of the people who are there at the moment. A project through a studio leads to a great moment of resilience and then it goes away. So, I think it's very episodic.*
>
> *– Jeff Carney, School of Architecture, Louisiana State University*

> *There is no [resilient design] program, there are just individual faculty that piece it together with other faculty in their departments or outside of their departments*
>
> *– Mary Comerio, Department of Architecture, University of California at Berkeley*

In addition to relying on a champion, resilient design education bumps up against barriers due to the organizational structures of universities. In most cases, students who want an interdisciplinary resilient design education must take classes outside of their major or department and the process of being approved to do so can be fairly cumbersome and act as a deterrent. Furthermore, the school or college in which resilient design programs are housed may affect the exposure students located outside these programs receive. Also, the collection of departments and programs within the school or college can facilitate or inhibit students from being exposed to resilient design educational offerings.

> *These institutional arrangements within colleges and universities, 'sets the stage for the ability for students to be exposed [to other disciplines].'*
>
> *– Andy Fox, Department of Landscape Architecture, North Carolina State University*

The competition for students in majors and the accounting of students in classes also poses institutional barriers to interdisciplinary resilient design education. Revenue is often generated based on the number of students in a classroom, which promotes competition between departments rather than collaboration, the latter of which is essential to developing and institutionalizing interdisciplinary resilient design education programs.

> *If I'm developing these courses and if I'm in charge of it, the way I get revenue is by students in the classroom. But then somebody over in economics is concerned about students 'going over there' or faculty going and teaching there. They don't like the idea of students going over and bleeding away from their program. But if they get compensated, then they like it. So that's how it goes.*
>
> *– Phil Berke, Department of Landscape Architecture and Urban Planning, Texas A&M University*

Accreditation standards for academic units also limit the number of elective courses, including courses taken by students outside of their discipline. Some fields have more course requirements than others due to accreditation standards and guidelines. Students majoring in engineering or architecture, for example, are restricted in the number of non-major courses that can be taken, thereby limiting their ability to enroll in resilient design courses or educational offerings in other departments, as explained below:

> *I think there are some hard barriers, particularly engineering... In undergrad, it's so tied to the accreditation process. Every school has to teach X, Y, Z and there's zero space for electives. And to change the curriculum you could risk losing your accreditation as an engineering school.*
>
> *– Sandra Knight, Research Engineer, Center for Disaster Resilience, University of Maryland*

> *In architecture, you need to be accredited, you have certain skills that everyone agrees are important. But with resilience you don't have that, which is why it happens in the interdisciplinary world.*
>
> *– Jeff Carney, School of Architecture, Louisiana State University*

Despite the recognition that an interdisciplinary education is an important aspect of preparing students to work in the resilient design field, those tasked with creating accreditation requirements have been slow to adopt metrics that would promote interdisciplinary resilient design curricula.

The incentive and reward structure for faculty promotion and tenure, such as publishing in high-impact disciplinary journals versus journals outside their discipline disincentivizes interdisciplinary collaborations. This is illustrated in the quote below:

> *There's an expectation that there's a certain level [of] engineering journal that is needed. Not that they wouldn't get credit but it would be looked at differently. I think we need to be advocates and reward that interdisciplinary approach.*
>
> *– Sandra Knight, Research Engineer, Center for Disaster Resilience, University of Maryland*

There are substantial challenges to expanding and institutionalizing resilient design education at U.S. colleges and universities, such as the siloed nature of university academic departments, schools and colleges, an incentive structure tied to the number of majors and students in courses, accreditation standards, and the metrics used to evaluate faculty for promotion and tenure.

The case study of UNC-Chapel Hill's Hurricane Matthew Disaster Recovery and Resilience Initiative provides an example of an inter-institutional, inter-disciplinary collaboration focused on responding to real world resilient design challenges in the aftermath of a disaster.

UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL | DEPARTMENT OF CITY AND REGIONAL PLANNING

Students and faculty from the University of North Carolina at Chapel Hill and North Carolina State University worked with residents and professional designers during a charette to explore the partial relocation of Princeville, North Carolina following Hurricane Matthew.

TRENDS IN EDUCATION

One emergent example of an innovative educational structure comes from the University of North Carolina at Chapel Hill, where students, faculty, and practitioners have collaborated to address resilient design challenges outside of the classroom.

HURRICANE MATTHEW DISASTER RECOVERY & RESILIENCE INITIATIVE

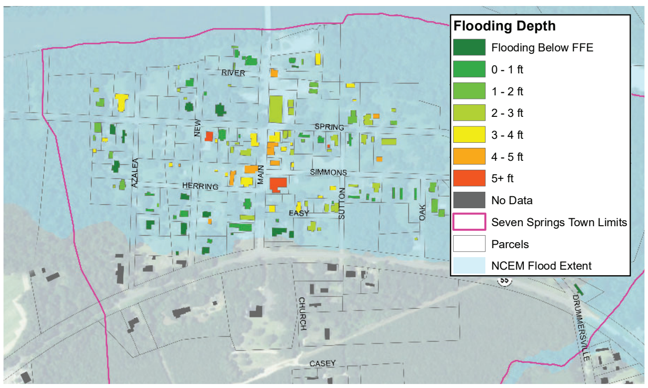
At the request of the Director of the North Carolina Division of Emergency Management and the Governor, the University of North Carolina at Chapel Hill's (UNC) Department of City and Regional Planning and North Carolina State University's (NC State) College of Design undertook a number of disaster recovery and design-related challenges that are not typically addressed by federal or state programs post-disaster. The issues were identified through direct interaction with local officials who cited areas in which they needed assistance. Of the more than 20 students that participated in this effort, most were selected from those pursuing a 10-credit-hour program in Natural Hazards Resilience at the University of North Carolina at Chapel Hill. Funding to support this initiative was provided by the North Carolina Legislature, the North Carolina Division of Emergency Management, and the University of North Carolina's Policy Collaboratory.

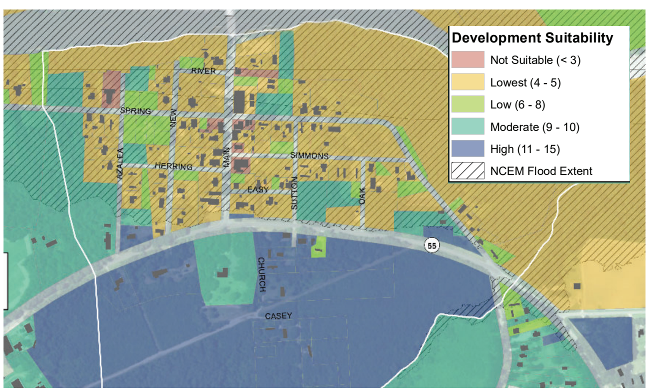
Through the Hurricane Matthew Disaster Recovery and Resilience Initiative (HMDRRI), planning, landscape architecture, and architecture students and faculty worked together with consultants to address unmet needs in six hard-hit towns in eastern North Carolina. These communities included Fair Bluff, Kinston, Lumberton, Princeville, Seven Springs, and Windsor. Faculty and students collaborated with consultants, state and federal agency staff, and elected officials at the local level to develop disaster recovery plans and strategies to enhance post-Matthew outcomes. Work included that undertaken at the Joint Field Office (JFO), a federal/state installation which housed employees from FEMA and the North Carolina Division of Emergency Management (the HMDRRI team had multiple offices in the building, including those for faculty and students that were co-located with top state officials). In addition, regular site visits were conducted to engage with local officials and members of each community. The ability to work directly in the JFO provided a unique opportunity for students and faculty to interact with a range of individuals and attend regular federal-state meetings. Direct community engagement included participating in open houses, public meetings, interviews with officials and residents, festivals and other public events, and design workshops.

Several projects resulted from this two-year interdisciplinary collaboration. They included: 1) conducting land suitability analyses that identified sites where new housing could be located outside the floodplain and within town boundaries to replace those flood-prone homes that were acquired and demolished, thereby reducing risk and minimizing the loss of tax base; 2) creating a series of home designs to support rebuilding resilient affordable housing; 3) writing a regional housing recovery strategy; 4) conducting an assessment of the financial standing of several towns, including conditions that might hinder their ability to recover; 5) conducting an assessment of possible flood retrofit techniques that could be applied in flood-impacted historic downtowns; and 6) developing open space plans for the vacant land created following the buyout of homes. Each of the projects were incorporated into community-level disaster recovery plans that also identified an integrative vision, a series of associated goals, and a collection of proposed policies and projects to help guide overall recovery efforts. Funding sources and appropriate organizations were identified to assist with the implementation of these actions.

Additionally, several design charrettes following Hurricane Mathew exposed students to interdisciplinary collaboration undertaken during compressed time frames typical of post-disaster activities. DesignWeek, held at NC State, involved teams of planning, architecture, and landscape architecture students and faculty working with communities impacted by Matthew, resulting in the development of strategies to address recovery needs and future long-term resilience through design and planning interventions. In Princeville, a five-day design charrette was held to create a design-based vision for rebuilding resiliently. Specifically, the charrette involved envisioning how the town could relocate residents and critical services to a 52-acre parcel of land purchased by the State of North Carolina that is located outside the floodplain, but adjacent to the town limits.

The design team worked closely with the North Carolina Division of Emergency Management, who not only provided funding to support the workshop, they also deployed teams to coordinate the overall event, including logistics (travel, lodging, food, and materials) and operations (IT support, security, and the credentialing of participants). This allowed the design team to focus on the task at hand. As an example of interdisciplinary resilient design education that is responsive to post-disaster needs and drawing on the expertise of emergency managers, HMDRRI provides a model for future inter-institutional, cross-disciplinary, and cross-sectoral collaborations undertaken in the post-disaster environment.





These images are part of a land suitability analysis conducted for the Town of Seven Springs. The color-coded building footprints represent flood levels. Meanwhile, the parcels are intended to inform areas best suited for the location of replacement housing based on a number of variables, including land located outside the floodplain, areas zoned residential, proximity to existing infrastructure, and land located within the town limits.

THE RELATIONSHIP BETWEEN PROFESSIONAL PRACTICE AND ACADEMIA

The private sector and professional realm of design related disciplines have a strong influence on what is taught to prepare students for jobs in these highly applied fields. Two aspects of professional practice that influence resilient design education include professional performance standards for fields such as engineering and building sciences and the client driven focus of design related professions.

For some professions, such as engineering and building sciences, there are professional building standards and guidelines that are set by professional associations. These standards have a strong influence on the curricula taught in U.S. colleges and universities. The lack of clarity and agreement as to whether these professional standards and guidelines promote resilient design poses a challenge to translating resilience principles into practice. There is no doubt that the building codes and performance standards have advanced our ability to design more resiliently than in the past, but there are instances in which there is uncertainty as to whether existing codes and standards are sufficient. Alternatively, there are examples of where construction standards outperform expectations, such as the American Society of Civil Engineers (ASCE) 24 Minimum Flood Design and Construction Standards being more stringent than is required by the National Flood Insurance Program (Personal Communication, John Ingargiola, July 6, 2017).

Outside the university setting, the professional world's influence on what is taught in the classroom poses challenges and opportunities to foster change. Client demand is a strong influence on what is taught in a university setting to prepare students for professional employment in their field. But clients are often concerned about the bottom line, and the effort put into designing, planning, and building more resiliently may cost more. Therefore, clients' concerns over costs may discourage better resilient design. Kofi Boone explains:

> “*Unless your client is pushing for that you might not want to do it.*”
>
> *– Kofi Boone, Department of Landscape Architecture, North Carolina State University*

Sometimes, clients, including businesses that hire designers and consumers (e.g. homeowners), need to be convinced about the economic value of designing resiliently, and that the benefits outweigh the costs, as explained by Jeff Carney:

> “*When thinking about the systems approach, sometimes the effort benefits the system and not just your client. Part of the work is making the actual resilient work pay back the client somehow like a lower insurance rate or some other dividend.*”
>
> *– Jeff Carney, School of Architecture, Louisiana State University*

Clients often want the cheapest solution. In some ways, changing the way we teach resilient design is related to demand side factors, such as what clients in a professional setting are willing to pay for. Clients often dismiss taking on additional costs for tackling broader, more systems-based resilient features in their projects. But, if clients were to internalize the long-term benefits of resilient design, they may begin to demand resilient design in their projects.

One barrier to realizing the benefits of resilience has been our inability to measure it in tangible, monetized, metrics that can translate into real cost savings. While the benefits of hazard mitigation investments have been demonstrated in the seminal study of the Multi-Hazard Mitigation Council (2005), which found a 4 to 1 return on investment, this has not necessarily been translated to widespread, systemic action among the design community. By 2017, this return on mitigation investment had increased to $6 in savings on future disaster costs for every $1 spent (National Institute of Building Sciences, Natural Hazard Mitigation Saves: 2017 Interim Report). Thus, there needs to be a strong market incentive in favor of resilient design for design professions to pivot their focus towards resilience. Furthermore, by better framing and messaging around how resilient design investments can reduce future disaster losses as well as how it benefits society (e.g. equitable, environmentally sustainable, economically sound), this approach may help to foster the greater adoption of resilient design principles.

Private sector firms that focus on resilient design from an interdisciplinary perspective have become increasingly ubiquitous. The series of disasters affecting cultural and economic centers in the U.S., including Hurricane Katrina and Sandy hitting New Orleans and the upper Northeast, as well as Hurricanes Harvey, Irma and Maria, have brought significant attention and opportunity for the private sector to be involved in resilient design work. As a result, many firms have tried to market themselves as resilience specialists to tap into a market that draws on interdisciplinary perspectives and prioritizes multi-scalar and systems-based thinking.

The private sector has started to take advantage of the benefits of interdisciplinary teams as they are adept at addressing the multi-scalar systems-based nature of resilient design problems. Sasaki, one such firm focused on resilient design, uses interdisciplinary teams to develop resilient design products.

> “ *We employ planners, landscape architects, architects, ecologists, and engineers in equal proportions. There is not one voice that dominates. We do projects on interdisciplinary teams.* ”
>
> *– Jill Allen Dixon and Brie Henshold, Practitioners, Sasaki*

GOALS AND ASPIRATIONS

Project Credit: Zixu Qiao, Texas A&M University

TOWARDS BETTER RESILIENT DESIGN CURRICULA IN THE U.S.

Based on our review of the literature, a scan of resilient design education across five disciplines at U.S. colleges and universities, and consultation with experts, we find that while the field of resilient design is growing, resilient design curricula is still a relatively new area of study that is unevenly delivered. While scholars and practitioners concur that resilient design education should incorporate knowledge about the interrelatedness of ecological, physical, and social systems, examine problems from an interdisciplinary systems perspective, and consider multiple scales, there are very few educational programs that incorporate all of these elements. Our study finds that resilient design curricula at U.S. colleges and universities is driven largely by individual scholars' interests in the topic and delivered in a piecemeal fashion. In many cases the lack of a comprehensive approach to resilient design curricula is due to strong institutional barriers and reward structures found in U.S. colleges and universities. To deliver a more robust curricula focused on resilient design, we provide the following goals and aspirations that will move U.S. colleges and universities towards delivering better resilient design curricula.

IMPROVE INSTITUTIONAL COMMITMENT

Universities must support individual commitments to resilient design education by scholars with a larger institutional commitment to resilient design education that spans multiple disciplines and associated departments. Universities must work to break down institutional barriers, such as allowing students to take courses outside their major and encouraging faculty to teach interdisciplinary courses. This can be achieved by incentivizing co-taught courses where both faculty members receive full course credit. Universities also need to create flexible incentive and reward structures that encourage resilient design education and research, such as course development grants, research grants, or course releases in order to develop interdisciplinary curricula, including those which may be triggered by disasters that occur unpredictably.

Given that much of the research in the field of resilient design is applied, universities and colleges should reward work done in this space, to include recognizing the merits of engagement in the promotion and tenure process. One way to do this is to revise promotion and tenure guidelines to value "engaged scholarship" that provides a service to the greater community. In addition, funding should be available to enable faculty and students to participate in field work both before and after disasters, to include providing readily available support to work in post-disaster settings on short notice (akin to the National Science Foundation's Rapid Grants and the HMDRRI case study). This will require a degree of staff and funding flexibility that remains uncommon at most universities. Universities and colleges should help to address this challenge by identifying faculty that are willing to engage in this type of work and recruit others. In some cases, this will necessitate identifying junior faculty that have yet to identify a clear research agenda, recognized mid- and senior-level hazards scholars committed to this approach, and a supportive administration willing to alter the status quo.

DEVELOP NEW CURRICULA MODELS AND ORGANIZATIONAL STRUCTURES

There are few universities that incorporate interdisciplinary, systems-based, and multi-scalar-elements of resilient design education into educational, research, and engagement opportunities. Universities must develop new curricula models and organizational structures that support this this type of educational offering. There are a few established programs across the country that offer promising models, as shown in our case studies. In addition, there are emerging programs that offer new degrees in resilient design, such as the Clemson University's Master's of Resilient Urban Design degree that offers an "issues-based, teamwork model wherein students engage with issues/questions based on a design-thinking foundation that is enhanced with methodologies and processes from multiple disciplines" (www.clemson.edu/caah/departments/architecture/programs/mrud/index.html). These new comprehensive degree programs should be evaluated and lessons should be drawn from them.

Design curricula benefits from a mix of education, research, and engagement activities and universities should provide more opportunities for this mix to thrive, particularly at research intensive colleges and universities. We realize that it is extremely difficult to develop new curricula models or reorganize institutional structures, so short of this goal, colleges and universities can incentivize the development of new courses or a certificate program. Course development and teaching could be supported by curriculum grants, or by funding the development of new degree programs focused on resilient design.

BUILD INTERDISCIPLINARY TEAMS

Resilient design is an inherently applied field that is also political in nature. Therefore, colleges and universities should build interdisciplinary teams to include a mix of faculty, practitioners, and policymakers to teach and mentor students. Centers and institutes are often the most successful units on campus at bringing together inter- and multi-disciplinary teams of students, faculty, researchers, and practitioners. Colleges and universities should provide funding to centers or other venues to incentivize interdisciplinary work. Practitioners, as part of this interdisciplinary team, can provide an up-to-date understanding of professional standards, guidelines (e.g. professional certification, recognized national standards and rules), and policies.

Practicing resilient design also requires thinking that goes beyond existing codes and standards (e.g. addressing challenges inherent in basing future decisions on past trends that are no longer accurate due to climate change) and fostering interdisciplinary thinking that may necessitate changes in current practice. Furthermore, the curricula should reflect the reality that designing resiliently requires understanding political and public policy realities. One major benefit of working in interdisciplinary teams during their education, is that students will be better prepared to work on resilient design projects in practice and interact and communicate with colleagues from diverse disciplinary backgrounds. This can make them more effective at designing resiliently.

EMPHASIZE FIELD AND STUDIO-BASED PROJECTS

Resilient design curricula benefits from a learning by doing approach that provides a platform to be innovative, allows students room to fail, and challenges teams to readdress complex, multi-disciplinary, multi-scalar problems. Field and studio-based projects should be a key element of any resilient design curricula because they provide a venue that enables students and faculty to explore the multi-faceted nature of challenges present in practice. The involvement of practitioners provides an additional element of reality and feedback, thereby challenging students with “real-world” problems, including the messiness of politics and public policy, creating designs with limited or changing information, and creating designs that reflect the manifestation of the existing policy milieu.

Field and studio-based projects can be delivered as part of a course or through a center or institute and should represent a substantial part of a student’s matriculation process. Considering most design schools already use studios as a required element of their curricula, this recommendation requires applying this method to resilient design problems and thinking, to include the post-disaster setting. Care should be taken to expand students’ knowledge and education beyond what clients in the field or studio-based courses want and to encourage students to be bold, critical, and consider ideas that the clients may not have asked for. The academy should allow for practical options combined with innovative, creative, and outside-the-box thinking. Ways in which this can be accomplished is through scenario or simulation-based studios that does not involve a client. Students should also have the opportunity to work with clients in studio-based courses to learn about applied projects but also granted the time and space required to engage in speculative exploration that might be beyond a client’s expressed needs.

CREATE FLEXIBLE AND RESPONSIVE CURRICULA

Post-disaster conditions provide rich learning opportunities. Therefore, colleges and universities should create resilient design curricula that are responsive to opportunities that arise, including capitalizing on post-disaster situations where design-thinking can result in tangible benefits to communities, states, and others as well as invaluable educational, research, and engagement opportunities for faculty and students. Colleges and universities should consider establishing resilient design strike teams capable of rapidly responding to post-disaster situations and needs and establish flexible funding sources and curricula that can be used when situational opportunities arise to include travel, student and faculty time commitments, and amendments to classes recognizing existing constraints. The curriculum should have in place a variety of different types of courses, such as 1-credit courses, 1-day courses, 5-day courses, mini-courses, or internship credits that can allow faculty to quickly respond in the aftermath of a disaster. Furthermore, allowing faculty to deliver these courses at flexible times, such as in between semesters or quarters, and during fall, winter, or summer break, provides greater opportunities for faculty to provide engaged learning opportunities in real time.

MEET THE NEEDS OF STAKEHOLDERS

In order to stay relevant, resilient design curricula should meet the needs of national, state, and local stakeholders. To facilitate this, colleges and universities should seek out partners external to the college/university that could serve as ongoing “clients” or sounding boards regarding curriculum content and the quality of products produced by students and faculty. Addressing these needs may take the form of design studios and fieldwork, to include the creation of specific design-based solutions provided at the end of discrete projects (classes) or as part of a long-term commitment to provide help as identified over time. It is incumbent on faculty, as well as university and college administrators, working with practitioners and clients to identify an array of opportunities that expose students to systems-based, interdisciplinary, multi-scalar design challenges. In an era of climate change, this should include addressing fundamental questions such as designing for non-stationarity and planning for uncertainty.

CONCLUSION

Project Credit: Zixu Qiao, Texas A&M University

The escalating costs of damage from disasters and the increasing intensity and frequency of weather-related events force us to think about how we educate and train future resilient design scholars and practitioners. Furthermore, the potential to save human lives and protect communities when we design more resiliently makes it imperative that we create and deliver high quality educational curricula in this area.

The organizational and incentive structures in U.S. colleges and universities pose many barriers to delivering a high-quality resilient design education. This report provides recommendations on how to eliminate these barriers and facilitate the delivery of an interdisciplinary, systems-based, multi-scalar education in resilient design. There are some external funding sources that may encourage this type of work, including the Enabling NSF Next Generation Hazards and Disasters Researchers Program that provides mentorship and training to junior scholars to increase the number of faculty committed to the hazards and disasters field, and the NSF Rapid Grants that allow for quick-response post- disaster research. But we need additional funding to conduct longer-term, sustained community engagement that would allow for a deeper university-community relationship that can have lasting effects on the design of places.

In addition, scholars and practitioners have a wealth of knowledge about what is needed to reduce the impacts of hazard events that is not being shared with students because of the limited and uneven educational offerings in resilient design curricula. To increase and improve resilient design education in the U.S. requires greater institutional commitment. This will take more financial resources and leadership at the highest levels within the academy.

The limited scope of this research did not allow us to examine a variety of questions that would be fruitful for future study. Future research could include an evaluation of international models of resilient design curricula. A comparative study of U.S. and international models would be instructive and beneficial to our understanding of resilient design education. This research was also limited to programs within the academic setting, however, future research could explore resilient design programs and educational offerings emerging outside colleges and universities, such as within government agencies or professional associations.

During the short period of this study, a number of degree programs focused on resilient design were created across the U.S. In addition, several universities have developed cluster hires – the hiring of a group of interdisciplinary faculty – to focus their research and teaching on resilient design. Future research should examine how the faculty hired as part of the cluster collaborate and engage to provide a more robust resilient design education that breaks free from academic siloes. This research identified a number of internal challenges and barriers to altering this problematic condition. Future research should therefore examine the "external" pressures to remain within these siloes, including higher education and external research funding practices.

There is an increasing demand to invest in the creation of an interdisciplinary, agreed-upon definition of resilient design and a methodology that can guide future resilient design scholars and practitioners. A final area for future research might ask: If an exemplary model for resilient design curricula that addresses the challenges of the twenty-first century could be developed, what would this look like? Future work in this area could develop guidelines for developing such curricula.

Our past experiences with natural hazards and disasters do not adequately prepare us for future events. Therefore, we need to reevaluate the curricula at U.S. colleges and universities in order to equip a new generation of students with the knowledge and skills to prepare for and respond to future disaster events. We must train future scholars and practitioners with the state-of-the-art knowledge that incorporates interdisciplinary, systems-based, multi-scalar thinking to design more resilient communities. If 2017 is any indication of the economic and human toll resulting from disasters that is yet to come, designing resilient structures, communities, regions, ecosystems, and economies will be more important than ever.

REFERENCES

Atran, S., Medin, D. and Ross, N.O. (2005). The cultural mind: Environmental decision making and cultural modeling within and across populations. *Psychological Review*, 112, 744-776.

Banks, J. A., Au, K. H., Ball, A. F., Bell, P., Gordon, E. W., Gutierrez, K. D., Heath, S. B. (2007). *Learning in and out of school in diverse environments: Life-long, life-wide, life-deep*. Seattle, Washington: University of Washington Center for Multicultural Education.

Beatley, T. (1998). The Vision of Sustainable Communities. *In Cooperating with Nature: Confronting Natural Hazards with Land-Use Planning for Sustainable Communities*. Chapter 8, Pp. 233-262. Washington, D.C.: Joseph Henry Press.

Beatley, T. (2009). *Planning for Coastal Resilience*. Washington, D.C.: Island Press.

Bell, P. Lewinstein, A., Shouse, A. W., and Feder, M. A. (Eds.). (2009). *Learning science in informal environments: People, places, and pursuits*. Washington, D.C.: The National Academies Press.

Berke, P. and T. Beatley. (1997). *After the Hurricane: Linking Sustainable Development in the Caribbean*. Baltimore, Maryland: Johns Hopkins University Press.

Berke, P., and Smith, G. (2009). Hazard mitigation, planning, and disaster resilience: Challenges and strategic choices for the 21st century. In U. Paleo (Ed.), *Building safer communities: Risk governance, spatial planning, and responses to natural hazards* (pp. 1-20). Amsterdam: IOS Press.

Burby, Raymond. (1998). *Cooperating with Nature: Confronting Natural Hazards with Land-Use Planning for Sustainable Communities*. Washington, D.C.: Joseph Henry Press.

Geis, Donald and Tammy Kutzmark. (1995). Developing Sustainable Communities: The Future is Now. *Public Management* (August): 4-13.

Godschalk, D.R., Kaiser, E.J., & Berke, P. (1998). Integrating hazard mitigation and local land use planning. In R. J. Burby (Ed.), *Cooperating with nature: Confronting natural hazards with land use planning for sustainable communities* (pp. 85-118). Washington, D.C.: Joseph Henry Press.

Godschalk, D.R., Beatley, T., Berke, P., Brower, D.J., & Kaiser, E. (1999). *Natural hazard mitigation: Recasting disaster policy and planning.* Washington, D.C.: Island Press.

Godschalk, David R. 2003. Urban Hazard Mitigation: Creating Resilient Cities. *Natural Hazards Review* 4(3): 136-142.

Hewson, M. G. (1992). Traditional healers in Southern Africa. *Annals of Internal Medicine,* 128, 1029-1034.

Hmelo-Silver, C. Marathe, S., and Liu, L. (2007). Fish swim, rocks sit, and lungs breathe: Expert-novice understanding of complex systems. *Journal of the Learning Sciences,* 16, 301-331.

Honwad et al. (2014). Education for sustainability and resilience in a changing climate. *Proceedings of International Conference of the Learning Sciences*, ICLS, 3, 1466-1473.

Mileti, D. (1999). *Disasters by Design: A Reassessment of Natural Hazards in the United States*. Washington, D.C.: Joseph Henry Press.

National Academies. (2012). *Disaster Resilience: A National Imperative*. Washington, D.C.: The National Academies Press.

National Science and Technology Council. (1996). N*atural Disaster Reduction: A Plan for the Nation*. Washington, D.C.: Subcommittee on Natural Disaster Reduction, National Science and Technology Council.

Norris, F. H., Stevens, S. P., Pfefferbaum, B., Wyche, K. F., and Pfefferbaum, R. L. (2008). Community Resilience as a Metaphor, Theory, Set of Capacities, and Strategy for Disaster Readiness. *Journal of Community Psychology 41*, 127-150.

O'Donnell, A. M., Hmelo-Silver, C., and Erkens, G. (Eds). (2103). C*ollaborative learning, reasoning, and technology.* New York: Routledge.

Orr, D. W. (1992). *Ecological Literacy: Education and the Transition to a Postmodern World*. Albany, New York: State University of New York Press.

Resnick, M. and Wilensky, U. (1998). Diving into complexity: Developing probabilistic decentralized thinking through role-playing activities. *The Journal of the Learning Sciences, 7*, 153-172.

Smith, G. (2009). Resilience Research Workshop, July 14. Broomfield, Colorado. Sponsored by the Community and Regional Resilience Institute. Panel presentation. Applications and Evaluation: What Approaches are Currently being Used to Assess Resilience?

Smith, G. (2014). Disaster Recovery in Coastal Mississippi, USA: Lesson Drawing from Hurricanes Camille and Katrina. *In Adapting to Climate Change: Lessons from Natural Hazards Planning*. Pp. 339-367. New York: Springer.

Smith, G., Martin, A. and Wenger, D. (2017). Disaster Recovery in an Era of Climate Change: The Unrealized Promise of Institutional Resilience. *In Handbook of Disaster Research, second edition*. Pp. 595-619.

Tierney, K., & Oliver-Smith, A. (2012). Social dimensions of disaster recovery. *International Journal of Mass Emergencies and Disasters,* 30(2), 123–146.

United Nations. (1992). Agenda 21. New York: United Nations.

Westcoat, J. L., and Khan, A. (2011). Disaster Resilient Design: Research and Teaching Initiatives in Pakistan.

World Commission on Environment and Development. (1987). *Our Common Future*. Oxford, England: Oxford University Press.

APPENDIX A: COLLEGES AND UNIVERSITIES

Delivery Method	Organization	Discipline	Program Name	Ba	Ma	PhD
Concentration	Harvard University	Design	Masters in Design - Risk and Resiliency Concentration		X	
Specialization	University of North Texas	E.M.	Degree specilization in emergency management		X	
Certificate	Texas A&M	Interdisciplinary	Environmental Hazard Management Certificate		X	X
	International Association of Emergency Managers	E.M.	Associate Emergency Manager (AEM) and Certified Emergency Manager (CEM) certifications			
	George Washington University	Interdisciplinary	Graduate Certificate in Homeland Security Preparedness and Response		X	X
	UNC Chapel Hill	Planning	Natural Hazards Certificate		X	X
Course(s)	California Polytechnic	Interdisciplinary	Disaster-Resistant Sustainable Communities			
	California Polytechnic	Interdisciplinary	Climate and Humanity: Human Impact on Earth	X		
	University of Oregon	L. A.	MA and BA of Landscape Architecture	X	X	X
	Louisiana State University	Interdisciplinary	Louisiana State University Coastal Sustainability Studio		X	
	California Polytechnic	Interdisciplinary	Sustainable Environments Minor	X		
	Columbia University	Interdisciplinary	MS in Architecture and Urban Design		X	
	Arizona State University	Planning	Masters of Urban and Environmental Planning		X	
	Massachusetts Institute of Technology	Interdisciplinary	MA of Landscape and Urbanism		X	
	Auburn	L.A.	MA Landscape Architecture		X	
	Pratt Institute	Interdisciplinary	MS in Sustainable Environmental Systems	X	X	
	Kansas State	Planning	MA in Regional and Community Planning		X	
	California State University - Chico	Geography	Major in Physical Geography	X		
	George Washington University	Interdisciplinary	Institute for Crisis, Disaster, and Risk Management		X	X
	Texas Tech	Interdisciplinary	Wind Energy Degrees and Certificate Program		X	X
	University of South Carolina	Interdisciplinary	Hazards and Vulnerability Research Institute	X	X	X
	University of North Texas	Interdisciplinary	Emergency Management and Planning Degree	X		
	University of Memphis	Earth Sciences	MS Earth Sciences with a concentration in Geophysics		X	X
Extension Program	Texas A&M	Interdisciplinary	Hurricane Awareness & Preparation Program for Coastal Extension Agents			
	Louisiana State University	Interdisciplinary	Extension Disaster Education Network			
	Clemson University	Interdisciplinary	Hurricane Safety and Preparedness			

E.M. stands for Emergency Management. L.A. stands for Landscape Architecture

Delivery Method	Organization	Discipline	Program Name	Ba	Ma	PhD
Research Center/ Institute/ Studio	University of Minnesota	Interdisciplinary	Resilient Communities Project	X	X	X
	University of Minnesota	Building Sciences	Center for Sustainable Building Research			
	California Polytechnic	Interdisciplinary	Resilient Communities Research Institute			
	Georgetown University	Public Policy	Georgetown Climate Center			
	Mississippi State University	Interdisciplinary	Community Design Studio			
	New Jersey Institute of Technology	Interdisciplinary	Center for Resilient Design			
	University of Arkansas	Interdisciplinary	Community Design Center			
	Tulane University	Interdisciplinary	Bywater Institute			
	Northeastern University	Interdisciplinary	Resilient Cities Lab		X	X
	Texas A&M	Interdisciplinary	Hazard Reduction and Recovery Center		X	X
		Interdisciplinary	Structures of Long-Term Disaster Recovery: Organizational Roles and Collaboration in Six Cities			
		Interdisciplinary	REU Site: Studies in Social Inequality and Social Vulnerability			
	Rice University	Interdisciplinary	SPPEED - Center for Severe Storm Prediction, Education, and Evacuation from Disasters		X	X
	Clark University	Interdisciplinary	The Marsh Institute	X	X	X
	Columbia University	Interdisciplinary	Center for Hazards and Risk Research		X	X
	East Carolina University	Interdisciplinary	Center for Natural Hazards Research		X	
	Florida International University	Engineering	Laboratory for Wind Engineering Research			
		Interdisciplinary	Laboratory for Coastal Research			
		Social Science	Laboratory for Social Science Research			
		Interdisciplinary	International Hurricane Research Center			
	Stanford University	Engineering	Blume Earthquake Engineering Center			
	University at Buffalo - SUNY	Interdisciplinary	MCEER: Earthquake Engineering to Extreme Events	X	X	
	Texas Tech	Interdisciplinary	National Wind Institute	X	X	X
	University of Arkansas	Interdisciplinary	Arkansas Earthquake Center		X	X
	Western Carolina University	Interdisciplinary	Program for the Study of Developed Shorelines		X	X
	University of Virginia	Interdisciplinary	Center for Risk Management of Engineering Systems		X	X
	University of Southern California	Interdisciplinary	South California Earthquake Center			
	University of Pennsylvania	Interdisciplinary	Wharton Risk Management and Decision Process Center		X	X
	University of North Carolina, Chapel Hill	Interdisciplinary	Coastal Resilience Center of Excellence		X	X
	University of New Orleans	Interdisciplinary	Center for Hazards Assessment, Response & Technology			
	University of Nebraska	Interdisciplinary	National Drought Mitigation Center			
	University of Memphis	Interdisciplinary	Center for Earthquake Research and Information			

APPENDIX B: INTERVIEWS

KEY INFORMANT INTERVIEWEE LIST

First Name	Last Name	Title	Institution
Phil	Berke	Professor Department of Landscape Architecture and Urban Planning	Texas A&M University
Kofi	Boone	Associate Professor of Landscape Architecture	North Carolina State University
Jeff	Carney	Associate Professor of Architecture	Louisiana State University
Mary	Comerio	Professor of Architecture	University of California, Berkeley
Reginald	DesRoches	Professor of Engineering	Georgia Institute of Technology
Jill	Dixon	Principal Planner	Sasaki
Andrew	Fox	Associate Professor of Landscape Architecture	North Carolina State University
Gerald	Galloway	Research Professor of Engineering	University of Maryland
Brie	Hensold	Senior Associate	Sasaki
John	Ingargiola	Lead Physical Scientist	Building Science Branch, FEMA
Sandra	Knight	Senior Research Engineer	University of Maryland
Terri	McAllister	Leader of Community Resilience Group	National Institute of Standards and Technology
David	Perkes	Professor of Architecture	Mississippi State University
James	Spencer	Professor of City and Regional Planning	Clemson University
John	van de Lindt	Professor of Civil and Environmental Engineering	Colorado State University
Shannon	Van Zandt	Associate Professor in the Department of Landscape Architecture and Urban Planning	Texas A&M University
David	Vaughn	Professor of Practice in Civil Engineering	Clemson University

KEY INFORMANT INTERVIEW PROTOCOL

Each structured interview consisted of two sections. First, a series of nineteen "general" queries were given to elicit attitudes about resilient design generally and as it relates to the interviewee's discipline.

The second section features a set of queries tailored to the discipline of the interviewee, including the prevalence, type, and quality of resilient design instruction.

The following explanation of the project was verbally provided to each interviewee before they were engaged in the structured interview:

- The focus of this study involves the review of existing college and university educational programs that teach resilient design approaches in the face of natural hazards, disasters, and climate change adaptation.

- Resilient design is defined as architecture, planning, engineering and building sciences that advances "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events" (National Research Council).

- The study emphasizes planning, architecture, landscape architecture, building sciences, and engineering programs that address the built, natural, and social environment, including how these elements are intertwined and help produce design solutions that are mutually reinforcing.

- An important sub-part of this effort involves the identification of multidisciplinary programs that bridge planning, architecture, landscape architecture, building sciences, and engineering.

- The impacts of climate change and extreme weather impose increasing risks to communities across the nation and world. These risks include sea level rise as well as increasing frequency of severe drought, storms, and floods.

- A key aspect of addressing these risks is planning and designing in ways that incorporate adaptability and uncertainty over time and relying on the utilization of the latest models that address the "non-stationarity" problem.

- That is, we are attempting to evaluate the latest thinking on how the design, planning, and development community should account for the new reality that hazards models can no longer rely on past events to predict the future. In many cases this is referred to as deep uncertainty and requires new thinking regarding how we adapt to what amounts to a new normal.

- We are reaching out to you as an expert in the field of disaster resilient design. The following set of questions are intended to help us gain a greater understanding of resilient design and to identify others in the field you think we should talk to. We would also like to reserve the ability to reach back out to you with additional questions if that's ok with you. If interested, we would be more than happy to provide the results of our study with you when completed.

SECTION 1 – GENERAL QUESTIONS:

G1. Please state your name and your title.

G2. Which of the following would you consider your primary technical field: Architecture, Landscape Architecture, Planning, Building Sciences, Engineering, Other?

G3. How would you briefly define resilient design within your field?

PROBE (for engineers) - What are the design standards that are considered “resilient” in your field?

NOTE: This may vary across hazard types. Examples include designing to the 1% chance annual flood, or designing for the 500-year return period earthquake.

Has the concept of resilience changed over time and if so, how has it changed?

G4. What is the scale of resilient design that your work (research, practice, and teaching) is focused on?

PROMPT: Building, neighborhood, city, region, or a combination?

NOTE: Need to capture research, practice, and education, especially if different.

G5. Who are the foundational scholars that define the field of resilient design? (NOTE: We may want to follow up with them about this question in order to ensure we get a full answer.)

Which scholars are currently at the forefront of resilient design in your field?

G6. Please list what you believe are key articles and texts that comprise foundational research in your field.

G7. Do you know of any schools/programs that excel in teaching resilient design? Please list them.

G8. Do you know of any programs that incorporate resilient design as a part of the core curriculum?

G9. What schools/programs are taking an innovative approach to teaching resilient design?

PROBE: Please describe what makes the program innovative.

NOTE: These might include working with identified clients, unique teaching methods, etc. (do not mention these unless they are struggling to answer).

G10. Do the programs you mentioned offer degrees, certificates, or minors?

G11. Are the programs supported by centers or institutes?

NOTE: Make sure you capture these responses and link them back to a specific university/ program/person, etc.

G12. To what extent is climate change science incorporated into how programs you've described are taught?

NOTE: Need a definition of climate change science here. Need to link comments back to specific courses, programs, etc.

G13. Does your field view climate change adaptation as part of resilient design?

PROBE: If yes, please describe how this is accomplished.

G14. To what extent are models, simulations, and scenario planning used in your field to inform resilient design teaching?

G15. To what extent are students in your field exposed to other disciplines that relate to resilient design?

NOTE: these may include architecture, planning, building science, engineering

PROBE: Please provide specific examples.

G16. Please describe educational programs in your field that do a particularly good job of teaching resilient design from an interdisciplinary perspective?

G17. What is the difference between teaching resilient design at the undergraduate versus graduate level?

G18. Is there anything we missed that you would like to tell us about?

G19. Is there anyone else you think we should talk to?

SECTION 2 – DISCIPLINE-SPECIFIC QUESTIONS

Architecture:

ARCH 1. We noticed many architecture programs incorporate sustainability into their curricula. Is there a way of discerning whether a program incorporates resilient design versus sustainability?

PROBE: How is resilient design distinguished from sustainable design in architecture?

ARCH 2. Are architects prepared at the undergraduate level to deal with resilience-oriented challenges?

PROBE: If so, how does this occur? Please be specific.

ARCH 3. Are architects prepared at the graduate level to deal with resilience-oriented challenges?

PROBE: If so, how does this occur? Please be specific.

ARCH 4. Are architecture programs addressing the issue of non-stationarity in an era of climate change?

PROBE: If yes, how is this occurring? Please be specific.

NOTE: Definition of non-stationarity: What is the latest thinking on how the design, planning, and development community should account for the new reality that hazards models that can no longer rely on past events to predict the future? In many cases this is referred to as deep uncertainty and requires new thinking regarding how we adapt to what amounts to a new normal.

Landscape Architecture:

LA1. Which programs incorporate new climate science research into teaching students about working with landscapes?

LA2. Are landscape architects prepared at the undergraduate level to deal with resilience-oriented challenges?

PROBE: If so, how does this occur? Please be specific.

LA3. Are landscape architects prepared at the graduate level to deal with resilience-oriented challenges?

PROBE: If so, how does this occur? Please be specific.

LA4. Are landscape architecture programs addressing the issue of non-stationarity in an era of climate change?

PROBE: If yes, how is this occurring? Please be specific.

NOTE: Definition of non-stationarity: What is the latest thinking on how the design, planning, and development community should account for the new reality that hazards models that can no longer rely on past events to predict the future? In many cases this is referred to as deep uncertainty and requires new thinking regarding how we adapt to what amounts to a new normal.

Planning:

PL1. Planning curricula are frequently divided into distinct specializations (transportation, economic development, land use, etc.). Is resilient design incorporated into particular planning specializations more than others?

PROBE: If so, where are the linkages strongest?

PROBE: Are there examples of resilience-based curricula that span specializations?

PL2. Should resilient design be incorporated into core planning curricula or be a specialization/ certificate?

PROBE: Why or why not?

PL3. Are planning programs addressing the issue of non-stationarity in an era of climate change?

PROBE: If yes, how is this occurring? Please be specific.

NOTE: Definition of non-stationarity: What is the latest thinking on how the design, planning, and development community should account for the new reality that hazards models that can no longer rely on past events to predict the future? In many cases this is referred to as deep uncertainty and requires new thinking regarding how we adapt to what amounts to a new normal.

Engineering:

ENG1. It appears that many engineering programs are focused on one hazard (e.g. earthquake engineering, coastal engineering, etc.) Why do you believe this is the case?

PROBE: Are there engineering programs that address multiple hazards?

PROBE: If yes, please list.

ENG2. Are there any hazards-based certifications that engineers can get?

PROBE: If yes, please list.

ENG 3. Do graduate certificates carry any weight in the engineering field?

PROBE: If yes, please list those that do.

PROBE: What makes these programs valuable?

ENG4. Are engineering programs addressing the issue of non-stationarity in an era of climate change?

PROBE: If yes, how is this occurring? Please be specific.

NOTE: Definition of non-stationarity: What is the latest thinking on how the design, planning, and development community should account for the new reality that hazards models that can no longer rely on past events to predict the future? In many cases this is referred to as deep uncertainty and requires new thinking regarding how we adapt to what amounts to a new normal.

Building Science:

BLDG1. How is the discipline of building sciences taught with resilience to disasters in mind?

PROBE: What are some examples of these techniques and standards?

BLDG2. In practice, how is building sciences being incorporated into resilient construction techniques and standards?

PROBE: What are some examples of these techniques and standards?

BLDG3. We noticed many building science programs incorporate sustainability into their curricula. Is there an way of discerning whether a program incorporates resilient design versus sustainability?

PROBE: How is resilient design distinguished from sustainable design in building sciences?

BLDG4. We found that some building science programs are in architecture or engineering departments while others are in construction science departments. How do the tenants of building science differ in relation to resilient design depending on the department it is housed in?

BLDG5. In those programs where there is little mention of resilience in relation to buildings sciences, do you see there being room for incorporating resilience into building sciences more explicitly in the future?

PROBE: Why or why not?

PROBE: If yes, how would this be accomplished?

BLDG6. Are building science programs addressing the issue of non-stationarity in an era of climate change?

PROBE: If yes, how is this occurring? Please be specific.

NOTE: Definition of non-stationarity: What is the latest thinking on how the design, planning, and development community should account for the new reality that hazards models that can no longer rely on past events to predict the future? In many cases this is referred to as deep uncertainty and requires new thinking regarding how we adapt to what amounts to a new normal.

Nonacademic practitioners, including employees from Andropogon and Sasaki, were asked a different set of questions, tailored to understanding the educational backgrounds of hired employees:

1. So that we have it correctly in our records, can you state your name and your title?

2. Which of the following would you consider your primary technical field: Architecture, Landscape Architecture, Planning, Building Sciences, Engineering, Other?

3. Your firm came up in our interviews as one on the forefront of resilient design - why do you think that is?

4. How would you briefly define resilient design within your field?

5. Has the concept of resilience changed over time and if so, how has it changed?

6. What is the scale of resilient design that your work (research, practice, and teaching) is focused on? PROMPT: Building, neighborhood, city, region, or a combination?

7. What programs/schools teach resilient design well? 7a. What are the aspects of the program or school that is specifically well taught?

8. When you are looking to hire a resilient design specialist, what programs or schools do you generally receive applications from?

9. To practice resilient design, what type of training or skills are necessary? 9a. What type of training or education would you consider necessary to practice resilient design but is not taught at universities?

10. Do employees come in with this training or is this training provided on the job? 10a. If on the job, what sort of training is provided on the job?

11. When you are looking to hire a resilient design specialist, are there any disciplinary

majors that are more well suited to having the skills necessary? 11a. Example: do you only hire from architecture, LA , planning, etc.

12. When looking to hire a resilient design specialist, does it matter if they have a bachelor's, master's or other certificate/credential?

13. What's the difference between a master's degree and a bachelor's with regard to the types of jobs you offer/task people with?

14. Is your focus on resilient design common within the field or is this a niche?

PROBE: What sort of momentum exists in this field to expand resilient design?

15. How does your practice feed back into resilient design education (i.e. training future resilient design practitioners)? What are the ways this happens?

16. That was the last question we had for you. Are there any questions you have for us? Is there anything that we didn't ask you that you would like to add to this conversation?

APPENDIX C: REVIEW COMMITTEE MEMBERS

COMMITTEE MEMBER LIST

First Name	Last Name	Institution
Kofi	Boone	North Carolina State University
Michael	Boswell	Cal Poly San Luis Obispo
Jeff	Carney	Louisiana State University
Jill Allen	Dixon	Sasaki
Andrew	Fox	North Carolina State University
Richard	Graves	Center for Sustainable Building Research, University of Minnesota
Eleanor	Hajian	Department of Homeland Security, Science and Technology Directorate, Office of University Programs
Brie	Hensold	Sasaki
John	Ingargiola	Building Science Branch, FEMA
Sandra	Knight	University of Maryland
Terri	McAllister	National Institute of Standards and Technology
Rob	Olshansky	University of Illinois
David	Perkes	Mississippi State University
Tim	Reinhold	Insurance Institute for Business and Home Safety Building Sciences
Michael	Rimoldi	Federal Alliance for Safe Homes
Bill	Siembieda	Cal Poly San Luis Obispo
Shannon	Van Zandt	Texas A&M University
David	Vaughn	Clemson University